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The Natural Sciences and Mathematics

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CORRECTION

The section devoted to Brazil in the February 1957 issue of the REVIEW OF EDUCATIONAL RESEARCH inadvertently carried the name of Anisio Teixeira as author. The author of the section was Mrs. Dinah de Souza Campos. The editors of the REVIEW regret this error.

This issue of the REVIEW was prepared by the Committee on the Natural Sciences and Mathematics

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INTRODUCTION

THE year 1957 has been one of unprecedented interest in and activity directed to the improvement of instruction in mathematics and science. This attention to mathematics and science is due to the national shortage of scientific and technical manpower, news about the quantity of science education in the Soviet Union, concern about the quality and quantity of instruction in these fields in American schools, and the recognition that science and mathematics have a role of new importance in American life today and hence, a new role in education. While much of this activity cannot be considered educational research, it serves to emphasize the need for research in the teaching of science and mathematics and should become a special stimulant to research in this field in the decade ahead. This number of the REVIEW OF EDUCATIONAL RESEARCH is consequently of added importance because of its timeliness.

The Committee on the Natural Sciences and Mathematics first proposed that the chapters be divided in terms of the purpose of the research rather than by grade level. However, after soliciting the assistance of authors, the grade-level division seemed to lend itself more readily to the review and writing task. It should be observed that the first consideration was more in keeping with the plan of the "Natural Sciences and Mathematics" number of the REVIEW for October 1948, and that the plan of this 1957 issue is more like that of the most recent issue in this field, October 1951, in which the grade-level approach was used for mathematics. The studies reviewed for the issue cover the six-year period since 1951.

Three chapters are unique to this issue. One of these is on studies of identification of gifted pupils, in which there is much current interest. It is the hope of the Committee that the chapter on implications of research in psychology for the teaching of science and mathematics will be of special help to the many groups now concerned about instruction in the sciences. Chapter IX gives a brief survey of current activities directed toward the improvement of science programs and teaching. One can look forward, especially in the area of curriculum where much work of promise is being carried out, to the next number of the REVIEW dealing with natural sciences and mathematics where the outcomes of these activities will be reported.

JOHN R. MAYOR, *Chairman*
Committee on the Natural Sciences
and Mathematics

CHAPTER I

Science in the Elementary Grades

DOROTHY C. MATALA and CLIFFORD G. McCOLLUM

MANY articles concerning elementary science appeared in educational literature during the past six years. A chief objective of the authors of the present chapter was to review reports of systematic research. Selection sometimes depended upon the exercise of personal judgment since some articles in periodicals were not precise in their description of the sources of data employed in reaching the generalizations stated. A few titles were included because they were excellent and detailed descriptions of methods or materials for use in elementary science.

Yearbooks and Handbooks

The Department of Elementary School Principals of the National Education Association (70) devoted its Thirty-Second Yearbook to the role and problems of elementary science in the school program. The Yearbook Committee secured written expressions of ideas and practices from approximately 80 elementary-school teachers, elementary-science specialists, and teacher educators thruout the country. These expressions were organized into 10 chapters composed of 62 separate articles. Areas dealt with included classroom experiences in science, elementary-school science content, methods of teaching science, use of community resources, and equipment and materials. Many tried and proven suggestions were given in this Yearbook, and its utilitarian nature made it a valuable reference both for the elementary-school administrator and the elementary-school teacher. Altho few specific references were made to formal research studies in science education, many of the recommendations were based upon results of studies that had been accumulating thru the years.

The American Association of School Administrators of the National Education Association (1) in its Twenty-Ninth Yearbook dealt with an area that is closely associated with the science program; namely, *Conservation Education in American Schools*. Conservation education thruout the total school program was considered in this publication, but attention to the teaching of conservation in the elementary schools was a very significant part of such chapters as those dealing with good teaching practices in rural schools, good teaching practices in city schools, instructional materials and facilities, and preservice education for teachers. The appendixes were especially noteworthy for their annotated bibliographies of selected references on conservation education, annotated lists of audio-visual materials, and descriptive lists of organizations and agencies concerned with conservation. The reading references were arranged in accordance with their applicability to the various grade levels. The entire

Yearbook was a sincere attempt on the part of the Yearbook Committee to point out the need for conservation education from primary grades thru high school and to provide illustrations of practical methods and materials usable in meeting this need. It should continue to exert its influence among administrators and teachers for some time to come.

The National Association of Biology Teachers felt that the Yearbook just described placed more emphasis on conservation education in the elementary schools than in the high schools. Consequently, it organized a National Conservation Committee that coordinated the preparation of the *Handbook for Teaching of Conservation and Resource-Use* (69). The *Handbook* placed greater emphasis upon teaching conservation in the high school, but many of the technics described were applicable to the elementary grades. Bibliographies and descriptions of free and inexpensive materials and audio-visual materials made up an important part of this work. The material was secured from many contributors thruout the country by means of state and regional chairmen alerted to locate good conservation teaching practices.

Reviews and Abstracts of Research Studies

The National Association for Research in Science Teaching regularly reviewed research carried on in elementary science during the period considered in the present review. One of the motivating factors in this practice was the decision of the American Educational Research Association not to devote a 1954 issue of the REVIEW OF EDUCATIONAL RESEARCH to science education. Anderson (2) described this program of the National Association for Research in Science Teaching, reported upon reasons for such an endeavor, and enumerated criteria that the organization had established in selecting research studies for review. Three types of studies were specifically listed as being worth attention: the experimental, the analytical, and the synthetic.

Science specialists (11, 16, 42) of the U. S. Office of Education, in cooperation with the National Association for Research in Science Teaching, collected information about and prepared abstracts of master's and doctor's theses dealing with science education. This was an excellent service to the research worker in science education and was frequently the only place results of many of the abstracted studies were published. Of the 1952 studies, 10 of the total of 75 summarized dealt with elementary science. Among the total of 46 summarized for 1953, 10 were concerned with elementary science. There were 71 included in the report for 1954, and 11 of these were elementary-science studies.

The annual reviews of the National Association for Research in Science Teaching began in 1954 with one by Buck and Mallinson (20) who surveyed research in the teaching of science at the elementary-school level completed from 1929 to 1952. The 82 studies reviewed were divided into three types: those dealing with curriculum development, those concerned

with learning in science, and those studying problems of teacher education. In curriculum development, the research reviewed indicated that elementary science had been steadily growing. Objectives were fairly well established and accepted by all, but implementation was lagging. It was agreed in theory that elementary science should be organized around subjectmatter areas, but practice still centered around the teaching of small, isolated topics. Many of the articles dealing with learning in science were statements of opinion. There were noticeable gaps in research concerned with the teaching of scientific attitudes and problem-solving skills. In the area of teacher education, there was evidence of a serious lack of training in science. Many studies presented recommendations for revised teacher-education programs, both in preservice and inservice phases.

The second annual review (3), published in 1954, included 17 elementary-science studies, most of them completed in 1952. Mallinson was chairman of the elementary-level committee for the third annual review (62) which selected 19 studies. There was a plea for the avoidance of needless repetition in science-education research and for attention to be directed toward improvement of methods for teaching science. Hubler was chairman of the elementary-level committee for the review published in 1956 (40). There were 12 references in the bibliography. Recommendations included the suggestion that status studies of the conditions in elementary science were in agreement and that the time was at hand to place emphasis on ways of improving the status.

Buck and Mallinson (21) prepared a nontechnical review of science-education research for the typical elementary-school classroom teacher. As in many of the other reviews, three large areas were considered: curriculum, learning and teaching, and teacher education. The authors recommended that research workers explore the literature available before undertaking studies, carefully examine aims of their studies, and direct their research toward the provision of solutions rather than the pointing out of additional problems.

Status Studies of Elementary-Science Programs

Craig (28) reviewed the development of elementary science during the past century. He pointed out that at one time children were thought incapable of interpreting events of the universe while today the interpretation of the total environment is considered a natural facet of child growth and development.

Brown (19) and Nelson and Brown (74) reviewed science-education periodicals, yearbooks, committee reports, recently published textbooks, and the opinions of experts to present a concise statement of trends in science education. Many of these trends concerned elementary science. It appeared that the schools emphasized more and more the role of science in everyday life, that science instruction was more generally thought of

as an integrated 12-year program, and that more attention was being directed toward enrichment opportunities in science.

During the period of the review there were numerous status studies completed in various geographical areas of the country. Auletto (5) surveyed the teaching of elementary science in Delaware; Bolen (12) worked in Oregon; Morlong (66), in Kansas; Challand (25), in Illinois; Greenlee (36) searched for trends in Florida; and Conrad (27) observed and questioned selected teachers in Cleveland, Louisville, Fort Wayne, Richmond, and New Castle. Questionnaires were common instruments of research in these studies with some use being made of interviews and observations. Conclusions in all the studies were similar. Problems that were located included lack of equipment and facilities, inadequate training of elementary-school teachers in science, difficulty in utilizing group procedures, and lack of time in the school program. There were some hopeful signs. Attempts apparently were made to integrate science with other subjectmatter areas and with other levels of the school program. Many different community resources were used. Teacher-education programs in science were improving at both the preservice and inservice stage.

Status studies need to be made, but it is possible that the span in time and location has not been great enough to justify all those now available. Increased emphasis needs to be placed upon research culminating in improved practices which can be shown objectively to be better than those previously used.

The Nature of the Child in Relation to Science

Interests

Studies of children's interests as related to science were popular; five will be reviewed here. Young (107) used general interest inventories, essays, and observations in identifying science interests. In addition, she devised two instruments of special note based upon projective technics.

These and other technics enabled Young (106) to identify the science interests of 129 children in Grades IV, V, and VI. Data were collected in the fall and again in the spring of one school year. It was found that the universe was the main interest of this group, with animals, the earth, growth and development of the human body, and weather also of major interest. There were some pronounced sex differences as was evidenced by boys being more interested in such areas as aviation and girls more interested in the growth and development of the human body. There was more interest expressed in science categories in which there had been planned experiences, and there was little interest expressed in books, movies, and television shows related to science. It was noted that a science program based upon the interests of the children in the fourth grade provided more experiences than did five textbook series for that grade.

Some research workers identified interests for the specific purpose of planning science units and activities around them. Jackson (41) carefully observed fifth-graders and found a unit on rocks to be of the greatest interest. Other units planned because of evident interests were on turtles, magnetism, electricity, sound and hearing, air, and the earth's surface. Smith (95) conducted a similar investigation with a first-grade class and consequently planned units on weather, animals, air, aviation, and seeds. Morton (67), working with intermediate-grade children, found that the use of different technics of identifying interests resulted in some confusion as to the exact rank of the leading interests. All technics used, however, showed strong interest in ancient plants and animals, and little interest in machines.

Bull (22) reported on case histories obtained by interviewing 100 high-school students having dominant science interests and hobbies. He concluded that these interests developed at an early age and recommended a program of science in the elementary grades which emphasized wide reading, activities, and science hobbies as the basis for development of science interests in normal children.

Studies of children's interests in science appear to produce conflicting results; it is difficult to generalize from them. Findings differ with different technics of identification, different groups of children, different geographic locations, and different times. Identification of interests is, however, of significance in providing one of the bases for school science experiences; more and more of the task evidently will have to be shifted to the individual classroom teacher in a specific situation.

Attitudes and Information

Brown (17, 18) surveyed the science information and attitudes possessed by elementary-school pupils in California. He selected pupils from the fifth and eighth grades on the basis of geographical location and sex and administered information tests and attitude tests to 2901 pupils in 14 urban, 9 suburban, and 18 rural schools. He found that rural pupils scored significantly higher on the information test. Boys scored significantly higher than girls on that test. Pupils from rural schools possessed more favorable attitudes than did those in the other two categories. Girls scored somewhat higher on the attitude test than the boys, but the difference was not statistically significant. On the basis of his findings Brown recommended that more attention be paid to the feminine applications of science and that science attitudes be taught rather than expected incidentally.

Schenke (89) attempted to locate the information sources used by children. He interviewed 22 first- and second-grade children repeatedly and rather intensively. He found that they obtained information from a wide variety of sources and that there was no marked sex difference as to sources employed. Nearly half learned from direct sources; the second most frequent source was other people. Only about one-tenth of the

named sources involved the influence of the school. The source had to be readily available in order to be significantly used. As might be expected the use of books increased greatly from the first to the second grade. Television programs were important sources.

Child Development

Research in child development will continue to provide implications for the science program. Three with particular reference to elementary science were those of Atkin (4), Farrell (33), and Serra (91). Atkin (4) analyzed children's ability to formulate and suggest tests for hypotheses in problem-solving tasks. He tested pupils in the first, third, and sixth grades, and found that they hypothesized readily at each grade level and that the accuracy of the hypotheses was about the same at all grade levels. All used empirical methods of testing hypotheses more than authoritarian methods altho the degree of permissiveness in the classroom affected this comparison. Children in a permissive classroom situation suggested empirical tests more often.

Farrell (33) studied the understanding of time relations of five-, six-, and seven-year-old children. The most growth was shown between ages five and six. Many cues were utilized by all ages in differentiating times. Better scores were achieved when questions involved personal, immediate, or repetitious events.

The comprehension by fourth-grade children of verbal abstractions was shown by Serra (91) to be related to background of information and to intelligence. She recommended that more emphasis be placed on developing the concepts that appear in primary-science materials since a good background of information is needed for good understanding. Special attention needs to be paid to the careful development of a background for verbal abstractions with the average or slow pupils in order for noticeable understanding to be achieved. Deductive as well as inductive approaches should be employed for optimum achievement.

Haupt (39) continued his series of investigations of concepts held by elementary-school children. This time he questioned young people about magnetism, and in comparing children's thinking with that revealed in the history of our race, he suggested that many primitive ideas were used to conceptualize the raw data of experience with magnets. Silano (94) followed a similar procedure in comparing pupils in the first grade with those in the third grade. Younger children were more concerned with what happened and the older with why it happened as they "played" with magnets and a group of articles. He implied from his observations that individual experimentation on the part of children is fruitful, that children are capable of discussing a problem, and that there is no good substitute for the reality of direct experiences.

Reid (84) analyzed the understanding of atomic energy concepts by fourth-, fifth-, and sixth-grade pupils before and after instruction. He

concluded that many children, particularly in Grades V and VI, could benefit in growth of understanding from instruction on atomic energy.

Kearney (44) found that the understanding of science concepts in Grade VI was definitely related to intelligence, reading ability, socio-economic status, and sex. Kerns (45), testing the understanding of 13 selected science concepts by pupils in Grades I thru XII, found that many concepts could be introduced earlier in schoolwork than they were and that many were encountered in the social realm before they were introduced into school study.

McCollum (50), attempting to correlate the child and his curriculum more closely, studied understanding of science and the use of cause-and-effect relationships with a technic of individual interview. Children in Grades I thru VI were interviewed to identify the nature of their explanations of natural phenomena. A pattern of maturation in the types of explanation and in the degree of understanding was discerned. It was suggested that such a procedure might be utilized in studying more carefully the individuals, as well as the group, in elementary-science classes.

One of the most intensive studies of the development of scientific concepts in children was conducted by Navarra (71, 72, 73). It was of a longitudinal type and involved only one child—his own son. With his wife as a co-investigator, he made observations of the child from age three years and two months until age six, and kept careful records. A number of technics for developing new concepts were identified, such as observation, experimentation, accidental discovery, and gradual refinement. A pattern of conceptual development was detected, but generalizations were avoided. Some determinants of this particular pattern seemed to be the parents' attitudes and the emotional quality of the concepts. Of particular importance was the recognition that the development of scientific concepts has been in progress long before the child comes in contact with the school.

The nature of the child is continually being studied. Elementary-science workers may well look to general studies of child psychology for a more nearly complete understanding of the child in relation to his environment. They may also hope for specific data with implications for elementary-science experiences.

The Elementary-Science Curriculum

The grade placement of science subjectmatter and the provision of teachers' guides for instruction continued to present problems deemed worthy of research. A number of investigations had as their objective the description of a science program. Galeno (34) described the cooperative procedure followed in developing an elementary-science program in the San Francisco Unified School District. Hamer (37) and Sailors (87) described steps employed in preparing units of study for specific classrooms rather than for an entire system. The generalizations of Pierce (79)

were of interest as he described curriculum trends in city school systems. He believed that science was being included more and more in the general curriculum for all pupils, that units of learning recurred at increasing maturity levels, and that curriculum guides for the complete science program were being developed with both vertical continuity and horizontal coordination.

The analysis of courses of study was the objective of research studies by Dubins (31) and Marsh (63). Dubins found little agreement in what subjectmatter to teach and found that most attention to course-of-study development was given in large city systems. Marsh compared contents of courses of study with opinions of experts as to what should be included and found them to agree rather well. The greatest disagreement located was in the general format of the courses of study.

Oxendine and Read (76) designed a procedure for grade placement of a physical-science principle. Classroom demonstrations were devised to teach the principle, "Sound is produced by vibrating material." These demonstrations were presented to fourth- and sixth-graders, and mastery was then compared in the two grades. Leonelli (47) developed criteria for desirable changes in pupil behavior as a basis for selecting physical-science principles to be included in the elementary-science curriculum. He enlisted the assistance of specialists and teachers in the application of the criteria and in the grade placement of the selected principles. He found that placement of specific principles was in groups of grades rather than in individual ones and that a gradation was accomplished with 64 of the 81 principles used in the study.

McCarthy (49) used ability to repeat a demonstrated experiment as a clue for age placement of selected science subjectmatter. McCollum (52) suggested that science maturity level might be identified by using a standardized interview schedule eliciting responses of identification, explanation, and generalization. This maturity level would be of value in providing appropriate experiences in the different grades.

Special areas of science were considered in relation to the total science curriculum. Bay (8) selected and tried earth-science material with fifth-grade classes. Pella and Solberg (77) showed that fifth-graders could work with atomic energy. Wedul (104) surveyed teaching of conservation in Minnesota elementary schools and teachers colleges.

Boyer (13, 14) evaluated contrasting science curriculums in the sixth grade by comparing pupil achievement. The curriculum which was judged more adequate in terms of the most widely accepted standards produced superior pupil achievement. The inadequate program handicapped slow-learning children more than those capable of rapid learning.

Luecking (48) analyzed the educational effectiveness of a three-year core program in Grades VI, VII, and VIII. Science achievement in high school was one of the bases for analysis. Core pupils were at least as well prepared for successful high-school work as those not in the core program.

Science for exceptional children was considered in investigations by Esposito (32) and McMahon (53). Esposito developed a teachers' guide of activities to teach principles about air, water, and sound to blind children. McMahon described a procedure for locating interests of mentally handicapped children with pictures they drew and with interviews. Having located interests in rockets and jets, he described ways of developing learning activities.

The Methods of Teaching Elementary Science

Fewer investigations were located dealing with this area of science education than with most. Some work in the development and trial of improved methods of teaching might well be encouraged. This kind of research is most readily converted into classroom practice.

Wailes (102) outlined a problem method for teaching science in grades I, II, and III. The outline was subjected to trial and was evaluated. Materials for six units were prepared, and these as well as the suggested procedures were criticized by the teachers using them and by a jury of specialists. Randomly selected children of the trial group were questioned as to their understandings after completing the unit. Four of the six units were judged satisfactory for the grade level at which they were taught, and the other two were accepted with some reservations. The method was judged satisfactory, and good results were achieved in pupil progress.

Josephson (43) used a variety of field-trip technics with first-grade pupils and found evidence of growth in problem-solving power, observation skill, and reporting ability. Schultz (90) systematically planned and tried a program for teaching ecology with a water-hyacinth community. This program was tried with a second grade and with a sixth grade with results judged satisfactory. Carlock (24) carefully formulated a plan of writing experimental procedures so as to be of greatest value to classroom teachers. His illustrative unit dealt with air pollution and might well serve as a guide for other teachers and units.

The use of arts activities with reading, science, and arithmetic was determined by Kohler (46) thru an analysis of teachers' guidebooks. In science, three different series of texts were considered. Many of the activities were found common to all. A greater variety of activities was found with reading and science than with arithmetic. More were used at the primary level than at other levels, and three-dimensional types were of more value in science teaching than two-dimensional ones.

A game method of evaluating science understanding was developed by Matthews (64). She used pictures and questions encouraging free talk with third-graders and found she could learn much about pupil growth and achievement by her method. This is an area to which research workers might well give serious attention. Evaluation technics for determining pupil progress in the achievement of many of the goals are notably lacking or are unvalidated.

The Relation of Reading and Science

The reading interests of children were shown by Rudman (85) to place science topics among the top-ranking categories. Children apparently do not read and ask about the same things, but science ranks high in both reading interests and asking interests. It was Rudman's belief that the science interests were being well-utilized in school activities.

Burkey (23) analyzed 41 recently published elementary-science textbooks for readability. He found extreme internal variations within textbooks and about as many with the most difficult third of reading matter in the beginning of the books as at the end. His general summation was that elementary-science textbooks were well written, but they might fit the character of their readers more closely thru further research and continued improvements in vocabulary control.

Mallinson (54), Mallinson and Buck (55), and Mallinson, Sturm, and Mallinson (59, 60) continued their investigations that were begun before the period of this review on the reading difficulty of texts. One study (55) analyzed unit-type textbooks and concluded that these, similar to standard textbooks, were liable to cause reading difficulty for the pupils for whom they were designed. In another study Mallinson (54) checked recent textbooks for readability to find out if improvements were being made and concluded that the recent texts were as variable in reading level and as liable to cause reading difficulty as the texts previously studied.

Hanlon (38) very carefully proceeded to show how a story with a first-grade vocabulary and a fourth-grade interest level might be written.

Beeler (9) examined science writings for children during the period from 1800 to 1952 in order to see whether the use of analogy therein had paralleled changes in educational procedure. He discerned no clear trend in the use of analogy and found the use of analogy to be erratic thruout the period of his study.

Shores and Saupe (93) conducted an investigation in reading for problem-solving in science. It was their belief, based upon their findings, that reading ability differentiates into somewhat specific abilities to read different kinds of materials for different purposes. It was their suggestion, however, that sharper measuring instruments were needed to test this idea more thoroly.

Nieri (75) turned the relation around and used science to teach reading in the first grade. She found her procedure to work satisfactorily and was convinced a first reader could be based on fact rather than fancy. It was her conviction that children are entitled to learning materials which are suitable to their thinking capacity and are challenging to their curiosity.

Resources for Teaching Elementary Science

A frequently mentioned problem in the teaching of elementary science is inadequate material and equipment. This prompted some workers to

consider resources available for the elementary-science teacher. Perhach (78) compiled lists of materials and equipment to be used with each of eight widely used science textbook series. West (105) prepared a detailed description of resources available in a particular community to be used with primary units she had developed. Barnett (7) determined some possibilities of using a marine environment as a resource for teaching. Pyle (83) made a careful annotated list of printed materials on fish and fisheries that could be used in children's camping programs. Tappe (100) explored the possibilities of use of junior museums.

Smith (96) considered library materials as effective resources and prepared an extensive annotated bibliography of science books for Grades IV, V, and VI. Straatman (98) developed a resource unit for study of health and personal development. DeKock (30) developed and compiled some descriptions of methods and materials for the study of insects.

In an attempt to consider facilities for teaching science, Sachs (86) developed a checklist and rating scale which would serve as a basis for evaluating the quality of facilities available in a school.

The Teacher of Elementary Science

Altho another chapter of this review deals with teacher education, it was felt some space should be devoted in this chapter to the numerous studies of the elementary-school teacher.

Piltz (80) surveyed elementary-school teachers in Florida to learn about their recognized difficulties in teaching science. Results were similar to those of other such studies; difficulties mentioned were lack of training, lack of interest, lack of time, and lack of materials. Genua (35) surveyed available research to compile a description of the education of teachers for elementary science. Pruitt (82) examined the published rules and regulations of the various state teacher-certification agencies and prepared tables showing the certification requirements for science teachers in the elementary and secondary schools. Mallinson and Sturm (58) compared science backgrounds and competencies of students from two different colleges who were preparing to teach in the elementary school. Recommendations included the suggestion that general physical-science survey courses would be better for elementary-school teachers than physics and chemistry.

Chamberlain (26) completed one of the most extensive status studies of the education of elementary-school teachers in science during the period of this review. He detected a trend toward including more of both academic science and professionalized science in the curriculum of the elementary-school teacher. McCollum (51) described the performance of prospective elementary-school teachers in a physical-science course with particular consideration of the factors in their background contributing to success in the course.

A good deal of research was concerned with developing and evaluating programs and courses for teacher education in science. Bredbenner (15) made an evaluative study of the conservation education program at the Iowa Teachers Conservation Camp. Stefaniak (97) tried to compare the relative effectiveness of lecture-demonstration and individual laboratory methods of teaching science to teachers by comparing achievements of their pupils. The results of the comparison varied from grade to grade. Bainter (6) compared the outcomes of two types of laboratory technics used in a course in physics. One of the technics involved an emphasis upon problem solving and seemed to have good potential for improvement over traditional methods. Tyndall (101) evaluated the effectiveness of the science education of elementary-school teachers who were graduates of Atlantic Christian College. Such procedures as were used by Tyndall might be used by others interested in judging their own programs.

Sauer (88) worked with direct experiences in college biology for elementary-school teachers. She determined the extent of use of direct experiences and suggested many opportunities for such activities. Weaver (103) arrived at criteria for selecting laboratory experiences for an integrated course in science for elementary-school teachers. Syrocki (99) formulated criteria for selection and development of laboratory experience units in biology for elementary-school teachers.

Mott (68) was interested in learning how their felt needs might affect the curriculum of primary-school teachers. In science, the practicality of the work for out-of-school situations as well as for in-school work was of some importance.

Inservice education programs were objects of research, too. Mork (65) tried to evaluate the effects of such a program by noting effects on the pupils of teachers involved. Results were favorable for the effectiveness of the inservice experience. Bingham (10) described what teachers wanted in science workshops. Shaw and Coccari (92) described how student opinions were of worth in the evaluation of student progress in a health-education workshop.

Implications of Research for Elementary-Science Education

Many articles have been written during the period of this review on the implications of the research in elementary-science education. Mallinson (54), Mallinson and Buck (55, 56, 57), and Mallinson (61) were active in reviewing, in suggesting applications for the classroom teacher, and in recommending research to be done. Croxton (29) strongly urged every teacher to become a researcher and pointed out needed research to be done by the classroom teacher. Price (81), writing as chairman of a committee of the Central Association of Science and Mathematics Teachers, identified needed research in the teaching of science.

Many individual pieces of research in elementary-science education have been completed; unfortunately the results of many were not made available to a wide audience of researchers and teachers. More attention needs to be paid both to the design of research studies and to their relationship with other available studies. Status studies have their contribution to make, but a crying need today is for the design, trial, and evaluation of better procedures for teaching science information, problem-solving technics, attitudes, and appreciations.

Bibliography

1. AMERICAN ASSOCIATION OF SCHOOL ADMINISTRATORS. *Conservation Education in American Schools.* Twenty-Ninth Yearbook. Washington, D. C.: the Association, a department of the National Education Association, 1951. 527 p.
2. ANDERSON, KENNETH E. "An Annual Review of Research in Science Teaching." *Science Education* 38: 6-8; February 1954.
3. ANDERSON, KENNETH E., and OTHERS. "Second Annual Review of Research in Science Teaching." *Science Education* 38: 333-65; December 1954.
4. ATKIN, J. MYRON. *An Analysis of the Development of Elementary School Children in Certain Selected Aspects of Problem-Solving Ability: A Study of Formulating and Suggesting Tests for Hypotheses in Science Learning Experiences.* Doctor's thesis. New York: New York University, 1956. 159 p. Abstract: *Dissertation Abstracts* 16: 1853; No. 10, 1956.
5. AULETTO, JOHN X. *The Teaching of Science in the Public Elementary Schools of Delaware.* Doctor's thesis. Philadelphia: Temple University, 1955. 246 p. Abstract: *Dissertation Abstracts* 15: 1357-58; No. 8, 1955.
6. BAINTER, MONICA E. *A Study of the Outcomes of Two Types of Laboratory Techniques Used in a Course in General College Physics for Students Planning To Be Teachers in the Elementary Grades.* Doctor's thesis. Madison: University of Wisconsin, 1955. 334 p. Abstract: *Dissertation Abstracts* 15: 2485-86; No. 12, 1955.
7. BARNETT, SUE M. *A Study of Our Marine Environment as a Florida Resource To Be Used in the Elementary Science Program.* Master's thesis. Tallahassee: Florida State University, 1953. 95 p. Abstract: Brown, Kenneth E.; Blackwood, Paul E.; and Johnson, Philip G. "Science Education Research Studies—1953." *Science Education* 39: 144; March 1955.
8. BAY, JAMES W. *Earth Sciences in the Elementary School Program.* Master's thesis. Detroit, Mich.: Wayne University, 1952. 171 p. Abstract: Johnson, Philip G. "Science Education Research Studies—1952." *Science Education* 38: 9; February 1954.
9. BEELER, NELSON F. *A Critical Examination of the Use of Analogy in Science Writings for Children.* Doctor's thesis. New York: New York University, 1954. 136 p. Abstract: *Dissertation Abstracts* 15: 204-205; No. 2, 1955.
10. BINGHAM, NELSON E. "What Elementary Teachers Want in Workshops in Elementary Science." *Science Education* 39: 59-64; February 1955.
11. BLACKWOOD, PAUL E., and BROWN, KENNETH E. "Science Education Research Studies—1954." *Science Education* 39: 372-89; December 1955.
12. BOLEN, VIRGIL A. *Science Teaching Facilities and Practices in Oregon Public Elementary Schools.* Doctor's thesis. Eugene: University of Oregon, 1952. 177 p. Abstract: Johnson, Philip G. "Science Education Research Studies—1952." *Science Education* 38: 11; February 1954.
13. BOYER, DONALD A. *A Comparative Study of Sixth-Grade Pupils' Science Achievement in Schools Having Contrasting Science Curriculums.* Doctor's thesis. Evanston: Northwestern University, 1952. 220 p. Abstract: Johnson, Philip G. "Science Education Research Studies—1952." *Science Education* 38: 12; February 1954.
14. BOYER, DONALD A. "A Comparative Study of the Science Achievement of Pupils in Elementary Schools." *Science Education* 39: 3-12; February 1955.

15. BREDBENNER, NOVELLA D. *A Study of Conservation Education Presented at the Iowa Teachers Conservation Camp from 1950 Through 1953.* Des Moines: Iowa State Department of Public Instruction, 1955. 156 p.
16. BROWN, KENNETH E.; BLACKWOOD, PAUL E.; and JOHNSON, PHILIP G. "Science Education Research Studies—1953." *Science Education* 39: 141-56; March 1955.
17. BROWN, STANLEY B. "Science Information and Attitudes Possessed by California Elementary School Pupils." *Journal of Educational Research* 47: 551-54; March 1954.
18. BROWN, STANLEY B. "Science Information and Attitudes Possessed by Selected Elementary School Pupils." *Science Education* 39: 57-59; February 1955.
19. BROWN, STANLEY B. "Trends in Science Education—1953." *Science Teacher* 21: 84-85; March 1954.
20. BUCK, JACQUELINE V., and MALLINSON, GEORGE G. "Some Implications of Recent Research in the Teaching of Science at the Elementary-School Level." *Science Education* 38: 81-101; February 1954.
21. BUCK, JACQUELINE V., and MALLINSON, GEORGE G. "Survey of Research in Elementary School Science Education." *School Science and Mathematics* 55: 677-82; December 1955.
22. BULL, GALEN W. *The Activities and Backgrounds of Pupils with Dominant Science Interests.* Doctor's thesis. Columbia: University of Missouri, 1954. 366 p. Abstract: *Dissertation Abstracts* 15: 61; No. 1, 1955.
23. BURKEY, JACOB E. *The Readability Levels of Recently Published Elementary Science Textbooks.* Doctor's thesis. Pittsburgh, Pa.: University of Pittsburgh, 1954. 81 p. Abstract: *Dissertation Abstracts* 14: 1328; No. 9, 1954.
24. CARLOCK, JOHN R. *Elementary Science Experiments—A Method of Planning Procedures.* Master's thesis. Normal: Illinois State Normal University, 1951. 78 p. Abstract: Brown, Kenneth E.; Blackwood, Paul E.; and Johnson, Philip G. "Science Education Research Studies—1953." *Science Education* 39: 156; March 1955.
25. CHALLAND, HELEN J. *An Appraisal of Elementary School Science Instruction in the State of Illinois.* Doctor's thesis. Evanston, Ill.: Northwestern University, 1956. 189 p. Abstract: *Dissertation Abstracts* 17: 568; No. 3, 1957.
26. CHAMBERLAIN, WILLIAM D. *Development and Status of Teacher Education in the Field of Science for the Elementary School.* Doctor's thesis. Detroit, Mich.: Wayne University, 1955. 205 p. Abstract: *Dissertation Abstracts* 15: 533-34; No. 4, 1955.
27. CONRAD, HALLIE M. *Science Practices Used by Selected Elementary Teachers.* Master's thesis. Muncie, Ind.: Ball State Teachers College, 1953. 51 p. Abstract: Brown, Kenneth E.; Blackwood, Paul E.; and Johnson, Philip G. "Science Education Research Studies—1953." *Science Education* 39: 144-45; March 1955.
28. CRAIG, GERALD S. "Elementary School Science in the Past Century." *Science Teacher* 24: 11-14; February 1957.
29. CROXTON, WALTER C. "Needed Research in the Teaching of Elementary Science with Every Teacher a Researcher." *Science Education* 39: 17-21; February 1955.
30. DEKOCK, WALTER E. *Some Methods and Materials for the Study of Insects in the Intermediate Grades.* Master's thesis. Cedar Falls: Iowa State Teachers College, 1954. 88 p.
31. DUBINS, MORTIMER I. *Current Practices in Elementary School Science with Reference to Courses of Study Published from 1940 to 1952, and the Extent of Activities Undertaken for the Improvement of Instruction.* Doctor's thesis. Boston: Boston University, 1953. 543 p. Abstract: Brown, Kenneth E.; Blackwood, Paul E.; and Johnson, Philip G. "Science Education Research Studies—1953." *Science Education* 39: 145; March 1955.
32. ESPOSITO, WILLIAM J. *The Development of a Teachers' Guide for Blind Elementary School Children That Will Illustrate Selected Principles of Physical Science Related to Air, Water, and Sound.* Doctor's thesis. New York: New York University, 1955. 199 p. Abstract: *Dissertation Abstracts* 15: 2114-15; No. 11, 1955.
33. FARRELL, MURIEL. "Understanding of Time Relations of Five-, Six- and Seven-Year-Old Children of High I. Q." *Journal of Educational Research* 46: 587-94; April 1953.

34. GALENO, RAMONA T. *The Cooperative Development of an Elementary Science Program in the San Francisco Unified School District.* Doctor's thesis. Stanford, Calif.: Stanford University, 1954. 147 p. Abstract: *Dissertation Abstracts* 14: 1630-31; No. 10, 1954.

35. GENUA, ALBERT J. "Backgrounds in Elementary Science Teaching." *Science Teacher* 24: 74; March 1957.

36. GREENLEE, JULIAN M. "Trends in Elementary Science Education in Florida Schools." *Science Education* 40: 224-28; April 1956.

37. HAMER, LOIS L. *Developing a First Grade Elementary Science Program in a Rural Community.* Master's thesis. Muncie, Ind.: Ball State Teachers College, 1954. 73 p. Abstract: Blackwood, Paul E., and Brown, Kenneth E. "Science Education Research Studies—1954." *Science Education* 39: 379; December 1955.

38. HANLON, MERCEDES. "Science Stories for Children." *School Science and Mathematics* 56: 32-38; January 1956.

39. HAUPT, GEORGE W. "Concepts of Magnetism Held by Elementary School Children." *Science Education* 36: 162-68; April 1952.

40. HUBLER, CLARK, and OTHERS. "Review of Recent Research in the Teaching of Science at the Elementary School Level I." *Science Education* 40: 338-41; December 1956.

41. JACKSON, FERN I. *Science Interests of Elementary Children and Activities Devised To Satisfy Their Interests.* Master's thesis. Muncie, Ind.: Ball State Teachers College, 1953. 81 p. Abstract: Brown, Kenneth E.; Blackwood, Paul E.; and Johnson, Philip G. "Science Education Research Studies—1953." *Science Education* 39: 147; March 1955.

42. JOHNSON, PHILIP G. "Science Education Research Studies—1952." *Science Education* 38: 8-38; February 1954.

43. JOSEPHSON, RUTH A. *A Study of the Value of Field Trips for the Teaching of Natural History in the First Grade Curriculum of the Fox Point-Bayside School, Fox Point, Wisconsin.* Master's thesis. Ithaca, N. Y.: Cornell University, 1952. 104 p. Abstract: Johnson, Philip G. "Science Education Research Studies—1952." *Science Education* 38: 19; February 1954.

44. KEARNEY, RUTH A. *Science Concepts of Sixth Graders.* Master's thesis. Flushing, N. Y.: Queens College, 1952. 10 p. Abstract: Johnson, Philip G. "Science Education Research Studies—1952." *Science Education* 38: 30; February 1954.

45. KERNS, LEROY R. *The Understanding of Thirteen Science Concepts by Students in Grades One Through Twelve.* Master's thesis. Greeley: Colorado State College of Education, 1952. 105 p. Abstract: Johnson, Philip G. "Science Education Research Studies—1952." *Science Education* 38: 20; February 1954.

46. KOHLER, RICHARD J. C. "Use of Arts Activities with Reading, Science, and Arithmetic." *Elementary School Journal* 52: 355-59; February 1952.

47. LEONELLI, RENATO E. "The Selection and Grade Placement of Physical Science Principles in the Elementary School Curriculum." *Science Education* 39: 54-57; February 1955.

48. LUECKING, EVELYN M. *A Descriptive Analysis of a Three Year Core Program and an Appraisal of Its Educational Effectiveness.* Doctor's thesis. Urbana: University of Illinois, 1956. 345 p. Abstract: *Dissertation Abstracts* 17: 577; No. 3, 1957.

49. MCCARTHY, FRANCIS W. *Age Placement of Selected Science Subject Matter.* Doctor's thesis. Cambridge, Mass.: Harvard University, 1951. 150 p. Digest: *Science Education* 36: 253-54; October 1952.

50. MCCOLLUM, CLIFFORD G. "The Determination of Science Maturity as a Means of Improving the Program in Elementary Science." *Science Teacher* 20: 238-40; October 1953.

51. MCCOLLUM, CLIFFORD G. "The Performance of Prospective Elementary-School Teachers in a General Physical Science Course." *Journal of Educational Research* 45: 695-704; May 1952.

52. MCCOLLUM, CLIFFORD G. "A Technique for Studying the Maturity of Elementary School Children in Science." *Science Education* 36: 168-75; April 1952.

53. MCMAHON, KENNETH V. "Science Program for the Educable Mentally Handicapped." *Exceptional Children* 21: 88-90; December 1954.

54. MALLINSON, GEORGE G. "The Five Most Needed Research Investigations in the Teaching of Science and in the Teaching of Mathematics." *School Science and Mathematics* 54: 428-30; June 1954.
55. MALLINSON, GEORGE G., and BUCK, JACQUELINE V. "Science Education Research and the Classroom Teacher." *Science Teacher* 22: 20-22; February 1955.
56. MALLINSON, GEORGE G., and BUCK, JACQUELINE V. "Some Implications and Practical Applications of Recent Research in Science Education." *Journal of Education* 137: 23-26; October 1954.
57. MALLINSON, GEORGE G., and BUCK, JACQUELINE V. "Some Implications and Practical Applications of Recent Research in Science Education: No. 2." *School Science and Mathematics* 56: 357-69; May 1956.
58. MALLINSON, GEORGE G., and STURM, HAROLD E. "The Science Backgrounds and Competencies of Students Preparing To Teach in the Elementary School." *Science Education* 39: 398-405; December 1955.
59. MALLINSON, GEORGE G.; STURM, HAROLD E.; and MALLINSON, LOIS M. "The Reading Difficulty of Some Recent Textbooks for Science." *School Science and Mathematics* 57: 364-66; May 1957.
60. MALLINSON, GEORGE; STURM, HAROLD E.; and MALLINSON, LOIS M. "The Reading Difficulty of Unit-Type Textbooks for Elementary Science." *Science Education* 39: 406-10; December 1955.
61. MALLINSON, JACQUELINE B. "What Have Been the Major Emphases in Research in Elementary Science During the Past Five Years?" *Science Education* 40: 206-208; April 1956.
62. MALLINSON, JACQUELINE B., and OTHERS. "Review of Recent Research in the Teaching of Science at the Elementary School Level." *Science Education* 39: 336-43; December 1955.
63. MARSH, MARJORY B. *Content Analysis of Selected Elementary Science Courses of Study Compared with Content Recommended by Some Selected Expert Teachers of Elementary Science.* Master's thesis. Muncie, Ind.: Ball State Teachers College, 1953. 40 p. Abstract: Brown, Kenneth E.; Blackwood, Paul E.; and Johnson, Philip G. "Science Education Research Studies—1953." *Science Education* 39: 149; March 1955.
64. MATTHEWS, UNA M. *A Technique for Evaluating Third Grade Children's Understanding of Some Science Terms and Principles.* Master's thesis. Austin: University of Texas, 1951. 100 p. Digest: *Science Education* 36: 254-55; October 1952.
65. MORK, GORDON M. A. *Effects of an In-Service Teacher Training Program on Pupil Outcomes in Fifth and Sixth Grade Science.* Doctor's thesis. Minneapolis: University of Minnesota, 1953. 304 p. Abstract: *Dissertation Abstracts* 13: 522-23; No. 4, 1953.
66. MORLONG, ORRIE. *Some Phases of Elementary Science in Eleven Counties in Kansas in 1951-52.* Master's thesis. Emporia: Kansas State Teachers College, 1952. 47 p. Abstract: Johnson, Philip G. "Science Education Research Studies—1952." *Science Education* 38: 26; February 1954.
67. MORTON, JAMES O. *Science Interests of Intermediate Grade Children.* Master's thesis. Salt Lake City: University of Utah, 1954. 82 p. Abstract: Blackwood, Paul E., and Brown, Kenneth E. "Science Education Research Studies—1954." *Science Education* 39: 384; December 1955.
68. MOTT, SINA M. "Curriculum for Primary Teachers." *Journal of Experimental Education* 22: 133-43; December 1953.
69. NATIONAL ASSOCIATION OF BIOLOGY TEACHERS. *Handbook for Teaching of Conservation and Resource-Use.* Danville, Ill.: Interstate Printers and Publishers, 1955. 499 p.
70. NATIONAL EDUCATION ASSOCIATION, DEPARTMENT OF ELEMENTARY SCHOOL PRINCIPALS. *Science for Today's Children.* Thirty-Second Yearbook. Washington, D. C.: the Department, 1953. 311 p.
71. NAVARRA, JOHN G. *The Development of Scientific Concepts in a Young Child.* New York: Teachers College, Columbia University, 1955. 147 p.
72. NAVARRA, JOHN G. "Elementary Science as It Relates to the Developmental Problems of Children." *Science Education* 37: 266-31; October 1953.
73. NAVARRA, JOHN G. "Scientific—From the Moment of Birth." *Childhood Education* 32: 179-86; December 1955.

74. NELSON, V. RONALD, and BROWN, STANLEY B. "Perceptible Changes in Science Education—1954." *School Science and Mathematics* 54: 690-94; December 1954.
75. NIERI, JEANIE. *Using Science To Teach Reading in the First Grade.* Master's thesis. San Jose, Calif.: San Jose State College, 1954. 114 p. Abstract: Blackwood, Paul E., and Brown, Kenneth E. "Science Education Research Studies—1954." *Science Education* 39: 385; December 1955.
76. OXENDINE, HERBERT G., and READ, JOHN G. *The Grade Placement of the Physical Science Principle "Sound Is Produced by Vibrating Material" in Relation to Mental Ages.* Doctor's thesis. Boston: Boston University, 1953. 124 p. Abstract: Brown, Kenneth E.; Blackwood, Paul E.; and Johnson, Philip G. "Science Education Research Studies—1953." *Science Education* 39: 151; March 1955.
77. PELLA, MILTON O., and SOLBERG, ELSE M. "What a Fifth Grade Learns about Atomic Energy." *School Science and Mathematics* 56: 719-24; December 1956.
78. PERHACH, ANDREW G. *Materials and Equipment for Elementary School Science.* Master's thesis. Normal: Illinois State Normal University, 1953. 55 p. Abstract: Brown, Kenneth E.; Blackwood, Paul E.; and Johnson, Philip G. "Science Education Research Studies—1953." *Science Education* 39: 151; March 1955.
79. PIERCE, PAUL R. "Curriculum Trends in City School Systems." *Science Education* 39: 223-24; April 1955.
80. PILTZ, ALBERT. *An Investigation of Teacher-Recognized Difficulties Encountered in the Teaching of Science in the Elementary Schools of Florida.* Doctor's thesis. Gainesville: University of Florida, 1954. 176 p. Abstract: Blackwood, Paul E., and Brown, Kenneth E. "Science Education Research Studies—1954." *Science Education* 39: 385; December 1955.
81. PRICE, HENRY V. "Needed Research in the Teaching of Science and Mathematics." *School Science and Mathematics* 57: 389-90; May 1957.
82. PRUITT, CLARENCE M. "Certification Requirements for Teachers in Elementary and Secondary Schools." *Science Education* 36: 182-93; April 1952.
83. PYLE, JEAN G. *Materials on Fish and Fisheries Management Published by the United States Government and the States—With Annotations and Discussions on Suitability for Use by Persons Without Technical Training and for Use in Children's Camping Programs.* Master's thesis. Ithaca, N. Y.: Cornell University, 1953. 104 p. Abstract: Brown, Kenneth E.; Blackwood, Paul E.; and Johnson, Philip G. "Science Education Research Studies—1953." *Science Education* 39: 152; March 1955.
84. REID, ROBERT W. *An Analysis of the Understanding of Certain Atomic Energy Concepts by Fourth, Fifth, and Sixth Grade Students.* Doctor's thesis. Greeley: Colorado State College of Education, 1952. 110 p. Abstract: Johnson, Philip G. "Science Education Research Studies—1952." *Science Education* 38: 29; February 1954.
85. RUDMAN, HERBERT C. "The Information Needs and Reading Interests of Children in Grades IV Through VIII." *Elementary School Journal* 55: 502-12; May 1955.
86. SACHS, MORRIS N. *A Program of Requirements and an Instrument for Appraisal of Science Facilities in Elementary and Junior High Schools in New York City.* Doctor's thesis. New York: Columbia University, 1953. 234 p. Abstract: Brown, Kenneth E.; Blackwood, Paul E.; and Johnson, Philip G. "Science Education Research Studies—1953." *Science Education* 39: 152; March 1955.
87. SAILORS, MARY B. *Some Steps in Building a Meaningful Science Program for the Elementary School.* Master's thesis. Muncie, Ind.: Ball State Teachers College, 1952. 85 p. Abstract: Johnson, Philip G. "Science Education Research Studies—1952." *Science Education* 38: 30; February 1954.
88. SAUER, PAULINE L. *Direct Experiences in College Biology for Prospective Elementary Teachers in the Midwest: Parts I and II.* Doctor's thesis. Ithaca, N. Y.: Cornell University, 1956. 372 p. Abstract: *Dissertation Abstracts* 17: 106; No. 1, 1957.
89. SCHENKE, LAHRON H. "Information Sources Children Use." *Science Education* 40: 232-37; April 1956.
90. SCHULTZ, IDA B. *A Way of Developing Children's Understanding of Ecology.* Doctor's thesis. Gainesville: University of Florida, 1955. 169 p. Abstract: *Dissertation Abstracts* 15: 2493; No. 12, 1955.

91. SERRA, MARY C. "A Study of Fourth Grade Children's Comprehension of Certain Verbal Abstractions." *Journal of Experimental Education* 22: 103-18; December 1953.
92. SHAW, JOHN H., and COCCARI, ANDREW S. "A Study of Some Aspects of Evaluation in a Health Education Workshop." *Research Quarterly* 25: 95-101; April 1955.
93. SHORES, JAMES H., and SAUPE, J. L. "Reading for Problem-Solving in Science." *Journal of Educational Psychology* 44: 149-58; March 1953.
94. SILANO, ALFRED A. "The Spontaneous Remarks of Children Concerning Magnetic Phenomena." *School Science and Mathematics* 52: 477-82; June 1952.
95. SMITH, GRACE A. *Science Interests of First Grades and Some Science Units Based on These Interests.* Master's thesis. Muncie, Ind.: Ball State Teachers College, 1954. 33 p. Abstract: Blackwood, Paul E., and Brown, Kenneth E. "Science Education Research Studies—1954." *Science Education* 39: 387; December 1955.
96. SMITH, RUBY D. *An Annotated Science Bibliography for Grades Four, Five, and Six.* Master's thesis. Austin: University of Texas, 1954. 159 p. Abstract: Blackwood, Paul E., and Brown, Kenneth E. "Science Education Research Studies—1954." *Science Education* 39: 387; December 1955.
97. STEFANIAK, EDWARD W. *A Study of the Effectiveness of Two Methods of Teaching Science in Grades Four, Five and Six.* Doctor's thesis. Boston: Boston University School of Education, 1955. 231 p. Abstract: *Dissertation Abstracts* 15: 2121; No. 11, 1955.
98. STRAATMAN, ZEGER W. *Resource Units for a Course of Study in Health and Personal Development for Sixth Grade Students.* Master's thesis. Seattle: University of Washington, 1954. 88 p. Abstract: Blackwood, Paul E., and Brown, Kenneth E. "Science Education Research Studies—1954." *Science Education* 39: 387; December 1955.
99. SYROCKI, B. JOHN. *Considerations in Selecting, Developing, and Validating Laboratory Experience Units in General Biology for Prospective Elementary School Teachers.* Doctor's thesis. Denton: North Texas State College, 1956. 198 p. Abstract: *Dissertation Abstracts* 17: 313-14; No. 2, 1957.
100. TAPPE, DOROTHY. *Junior Museums with Special Reference to Bridgeport, Connecticut's Wonder Workshop Junior Museum.* Master's thesis. Ithaca, N. Y.: Cornell University, 1953. 40 p. Abstract: Brown, Kenneth E.; Blackwood, Paul E.; and Johnson, Philip G. "Science Education Research Studies—1953." *Science Education* 39: 154; March 1955.
101. TYNDALL, JESSE P. *The Teaching of Science in Elementary Schools by Recent Graduates of Atlantic Christian College as Related to Their Science Preparation.* Doctor's thesis. Gainesville: University of Florida, 1956. 144 p. Abstract: *Dissertation Abstracts* 16: 918; No. 5, 1956.
102. WAILES, JAMES R. *The Problem Method in Science in Grades One, Two and Three.* Doctor's thesis. Iowa City: State University of Iowa, 1954. 241 p. Abstract: *Dissertation Abstracts* 14: 2300; No. 12, 1954.
103. WEAVER, ALLEN D. *A Determination of Criteria for Selection of Laboratory Experiences Suitable for an Integrated Course in Physical Science Designed for the Education of Elementary School Teachers.* Doctor's thesis. New York: New York University, 1954. 387 p. Abstract: *Dissertation Abstracts* 15: 238-39; No. 2, 1955.
104. WEDUL, MELVIN O. *Conservation Education in Selected Minnesota Elementary Schools and State Teachers Colleges, 1954.* Doctor's thesis. Boulder: University of Colorado, 1954. 179 p. Abstract: Blackwood, Paul E., and Brown, Kenneth E. "Science Education Research Studies—1954." *Science Education* 39: 389; December 1955.
105. WEST, MARY A. *Environmental Resources for Teaching of Science in the Primary Grades.* Master's thesis. Muncie, Ind.: Ball State Teachers College, 1954. 63 p. Abstract: Blackwood, Paul E., and Brown, Kenneth E. "Science Education Research Studies—1954." *Science Education* 39: 389; December 1955.
106. Young, Doris A. *Factors Associated with the Expressed Science Interests of a Selected Group of Intermediate Grade Children.* Doctor's thesis. Evanston, Ill.: Northwestern University, 1956. 397 p. Abstract: *Dissertation Abstracts* 17: 318-19; No. 2, 1957.
107. YOUNG, DORIS A. "Some Techniques for Identifying Children's Science Interests." *School Science and Mathematics* 57: 462-64; June 1957.

CHAPTER II

Mathematics in the Elementary Grades

E. GLENADINE GIBB and H. VAN ENGEN

RESEARCH related to the arithmetic curriculum has had much influence on teaching procedures, content of arithmetic at various grade levels, organization of instructional groups, and programs of curriculum improvement. Certain research findings, once widely accepted, were re-evaluated during the period under review.

Summaries and Bibliographies

Six years ago Burch and Moser (16) reviewed in a similar issue of this publication the research of the previous three-year period. Since that time there have been several summaries and interpretations of research. In annual annotated bibliographies Hartung (48) presented selected references pertaining to instruction in arithmetic in the elementary school. Wrightstone (112) summarized selected research studies that have influenced instruction in arithmetic, noting that mature and successful teachers are far from being in complete agreement with or accepting current research findings and judgments of experts. Gibb (34) summarized experimental investigations which compared methods of teaching; she also prepared a selected annotated bibliography (35) for the classroom teacher interested in action research. In publications sponsored by the Association for Supervision and Curriculum Development and the American Educational Research Association, both departments of the National Education Association, Glennon and Hunnicutt (37) and Morton (70) examined research for its implications for the classroom teacher. Pikal (81) reviewed research related to methods of teaching, to concepts learned, and to the use of arithmetic outside the school in the teaching of arithmetic in the upper elementary grades. Weaver (106) summarized the research related to elementary-school mathematics for the years 1951-1956, presenting an annotated bibliography and some concluding observations concerning research during that period of time.

Methods of Instruction

No longer is research limited to emphasis on 100-percent accuracy in computation such as that summarized by Wilson (108) in a study of the mechanics of computation. In a review of research dealing with the effect of instructional procedures on achievement in fundamental operations in arithmetic, Hightower (51) suggested that superior instruction and motivation may be more important than the mechanics of the method used.

Evidence continued to accumulate in support of the discovery method of teaching whereby children are encouraged to structure mathematical concepts. Dawson and Ruddell (21) reviewed four studies showing what is to be gained thru the "meaning method" of teaching arithmetic. As the result of the Los Angeles study, Miller (69) reported that in comparing the "meaning" and "rule" methods of teaching, the "meaning" method was more effective for the areas of (a) computation of fractions, (b) establishing retention, (c) processes of computation, and (d) the understanding of the principles of arithmetic needed to comprehend complex analyses in arithmetic.

In investigating the possibilities of teaching arithmetic by television, Strueve (96) found it opened a way for better understanding of present-day method, extended the influence of a superior teacher to many classrooms, and gave regular teachers more opportunity to help individual children. Articles in *Emerging Practices in Mathematics Education* (72) presented other classroom procedures.

Learning

Closely associated with research on methods of instruction were studies concerned not with the products of learning but with the process of learning. The Twenty-First Yearbook of the National Council of Teachers of Mathematics, *Learning of Mathematics*, (73) discussed important aspects of learning, theories of learning, motivation, formation of concepts, sensory learning, language, drill, transfer of training, problem solving, individual differences, and improvement of instruction. Purdy and Kinney (86) presented a series of lessons as a sample of effective procedures that may be interpreted theoretically to describe a planned sequence for effective arithmetic learning. Buswell and Kersh (17) studied thought patterns in an effort to determine objectively general patterns of problem solving. They found the most striking characteristic to be the variety rather than the similarity in sequence of thinking. Van Engen and Gibb (103) found the general idea approach to learning more effective than a method of unit skills. Plank and Plank (82) identified the emotional components in arithmetical learning thru autobiographies of scientists, statesmen, and musicians in an effort to determine why many people have not learned mathematics. Baldwin (5) indicated an unexplored area of psychological research as he discussed number forms and mental imagery.

Abilities and Attitudes

Related to the thought patterns of learning are the ability to learn arithmetic and the attitude toward it. In a study of cognitive factors associated with progress of children in arithmetic, Barakat (6) found that innate intelligence appeared to contribute the largest part to mathematical

attainment. He also found ample evidence for a specialized factor in mathematical ability, its components being mathematical reasoning and a symbolic factor allied to mechanical computation and rote memory. Emotional instability correlated most highly with inaccuracy of computation, and lack of industry with inefficiency in mathematical reasoning.

An attitude scale constructed by Dutton (24) was used to estimate general attitude toward arithmetic. Grades V and VI were the most crucial in developing attitudes. Lynn (63) found a tendency for anxiety to be associated with good reading and poor arithmetic.

McAllister (64) attempted to find a relation between degree of development of arithmetical concepts and intelligence, attention span, and ability to do both formal and functional arithmetic. Poffenberger and Norton (83) examined factors affecting pupils' attitudes toward arithmetic. It appeared that parents and teachers were in the main responsible for pupils' positive or negative attitudes.

Concepts of Children

Martin (67) studied the spontaneous reactions of young children, confirming findings of previous studies that with advance in age, young children increase in their ability to handle concepts of number, size, and quantity as measured in formal test situations. It was noted that a child who at first viewed collections of objects as a whole in terms of a single characteristic later readily identified specific objects and subgroups of objects. In another study of number concept, Ilg and Ames (56) found the errors that children made to be the best clues to a child's stage of development. Emphasis should then be placed on kinds of errors made, not on right and wrong answers. In investigating the development of children's understanding in the four fundamental processes, Deans (23) found that children dropped less mature responses in favor of more mature processes.

In a descriptive study of responses to nine problems, Gunderson (40) attempted to discover thought patterns of young children in solving multiplication and division problems before they had been taught the processes, directing attention to the need for readiness material for multiplication and division. The study indicated that measurement division was more easily understood and applied than was partitive division and that probably division as a process should be introduced thru measurement problems.

Springer (95) designed a study to ascertain what children know about the appearance and operation of a clock prior to formal school instruction. Trends in drawings showed that maturation of ideas and abilities to express those ideas were enhanced by an increase in incidental experiences and observations. Piaget (80) described some experiments which indicated the essential idea of number development in children; he suggested that

the historical development of geometry is reversed for children. Pratt and others (84) studied children's abilities to designate magnitude of indeterminate numbers as few, hardly, scarcely, several, some, lot, and many. Priore (85) tested children entering first grade to discover their knowledge of arithmetic. Flournoy (29) examined children's thought processes in higher-decade addition. She concluded that unless children were helped to establish a pattern of thinking which enabled them to perform higher-decade addition almost as if in one complete thought, they were likely to devise time-consuming and perhaps inaccurate ways of adding a column of figures. In a study of children's thought processes in subtraction, Gibb (33, 36) found that children responded to the action of the problem situation in solving the problem. She concluded that this caused difficulty in various additive and comparative situations which are commonly processed by subtraction.

Number

Dawson (20), proposing complexity as a critical factor in apprehension of number as a group, found that the use of complicated pictures tended to produce counting, not grouping, and hence did not assist the learner in developing ability to recognize number groups. Woods (110) sought to discover whether children's arithmetical ability would be improved if they were taught to apprehend as groups certain lines in straight-line patterns. He found a low positive correlation between ability to group and general achievement in arithmetic skills. No significant improvement in arithmetic achievement resulted from special training in apprehending groups.

Operations

Thyne (98) made inquiry into the nature of error in the addition facts, summarizing types of errors and conditions of occurrence and concluding that orders of difficulty were of no real value. In a study of subtraction Weaver (107) found that it would be advantageous for all children to begin with a common method of compound subtraction—decomposition —and then follow different procedures. Meddleton (68) compared the results arising from the systematic practice of carefully compiled and graded number combinations, with results from the ordinary "laissez faire" procedures of presentation and practice. Conclusions were that children made more arithmetical progress with systematic revision sheets, that organized material was of slightly more benefit to the children in poorer socioeconomic areas, and that more improvement was made in subtraction and division than in multiplication and addition. Crumley (19) found that regardless of the method of teaching subtraction children had almost a universal understanding of subtraction as a "take-away" process. Rheins and Rheins (87) tried to determine whether the method of decom-

position, or the method of equal addition, was superior in speed and accuracy in compound subtraction of whole numbers five years after the process had been taught. Results of their research did not favor one method strongly. Bebb (7) compared a classroom method of teaching basic multiplication facts with a tachistoscopic presentation, finding the latter to be only an interesting and varied method of learning. Similar findings by Phillips (79) indicated that tachistoscopic methods are effective but no more effective than the ordinary workbook method of practice.

Brownell (13) reported that children often found division difficult because they had inadequate mastery of skills and facts basic to success in learning. He (14) believed it better to have mastery of subskills in division before going on with more problems in division. Dawson and Ruddell (22) compared the effectiveness of common textbook practices in introducing the division of whole numbers with an experimental procedure based on a subtractive approach and a greatly expanded use of visualization devices. These authors found higher achievement, greater retention, and increased ability to solve examples in a new situation where the experimental method was used. In another study Van Engen and Gibb (103) used visual material in the conventional and in the subtractive methods of division. They, too, found a greater ability to transfer learning to new situations among those using the subtractive method. However, achievement and retention were not different for the two methods. Benz (8) presented data showing how applications of two rules do not produce correct quotient figures. In a critical summary of research in estimating quotients, Hartung (47) brought to the reader's attention aspects of issues which have been largely neglected in estimating quotients. He considered advantages in using a trial quotient that is smaller than the true quotient and the relative simplicity of a "one rule" procedure. Thruout the literature on the teaching of division, questions were raised regarding measurement and partition ideas in division. Moser (71) described some exploratory work in thinking of division as finding either the number of groups or the size of one group. Hill (52) discussed the use of measurement-type situations to introduce the idea of division.

Fractions

In a thoughtful discussion of fractions, Riess (88) observed that much valuable material on the history of fractions presented in scientific writings has been neglected. She also suggested that fractions be approached from the standpoint of multiplication rather than division. Brooke (11) compared two methods of introducing division of fractions. Results indicated that the common denominator method might be more successful for use in introducing the idea of a whole number by a fraction if there were no remainders in the answer. Aftreth (2, 3, 4) determined the effect on the learning process of the identification and correction of typical errors embedded in exercises in addition and subtraction of fractions.

Apparently, at least in the early stages, learning was not adversely affected. Results from Johnson's study (57) showed that it was easier to learn to use decimals than common denominators in addition and subtraction of fractions; a case was presented for teaching decimals first. Lankford and Pattishall (59) reported that allowing pupils much freedom and exploration in working with fractions was a sound teaching procedure. Hirsch (53) discovered that three test questions involving the division of fractions, altho essentially of the same type, did not represent the same degree of difficulty to pupils. One question was identical with examples in the text; children found it easier. The other two questions were phrased in terms only slightly different, and involved the same principles, but the pupils found them considerably more difficult.

Problem Solving

Much has been written regarding formal analysis in problem solving. Burch (15) found that children tended to score higher on tests not requiring them to go thru steps of formal analysis. Thinking more carefully about size, relationships, and dynamics of quantities described in each problem seemed a more profitable attack. Gunderson (39) described the variation in children's responses to problem situations and indicated that there was no one pattern for all children.

From a questionnaire investigation, Ullrich (99) found a difference of opinion among teachers, superintendents, and writers regarding the extent to which problem answers should be labeled. Much of what writers of textbooks know about acceptable answers is not always known by elementary-school teachers.

Van Engen (101) suggested a fertile field of research by noting that children learn to recognize what process to perform by visualizing what operations are indicated by the words in the problem.

Measures

According to McLatchy (66) preschool children have a better understanding of measures of time than of other conventional measures. Wilson and Cassell (109) summarized the research related to what should be taught in weights and measures. Cassell concluded that the experience factor should determine the teaching of weights and measures, for some commodities may be sold in different units in different sections of the country.

Mental Arithmetic

Hall (42) presented a case for his definition of mental arithmetic after summarizing meanings given to the term. In another investigation he (41) identified uses of mental arithmetic made by business people during one

day's business affairs. Mechanical computing devices have not replaced the need for mental arithmetic.

Petty (77) studied the effectiveness of a non-pencil-and-paper method of solving verbal problems in arithmetic, finding that pupils trained in the method tended to use pencil and paper less.

Flournoy (31) found that oral arithmetic gave pupils greater confidence and understanding of the written word problem. Spitzer and Flournoy (94) gave attention to verbal problems.

Evaluation

Hannum (45) constructed and standardized a test of arithmetical skills and abilities for individual use with children from preschool to the second-grade level. This instrument should have value for an arithmetic readiness program in the primary grades. Wrightstone (111) reported the results of building a test of arithmetical meaning for Grades I and II. McKenzie (65) described procedures used to standardize *Vernon's Graded Arithmetic Test.*

In recent years there have been charges against the Three R's in our schools. Lanton (60) showed that a selected population of third- and fifth-grade children achieved higher scores on standardized educational tests than did a comparable group tested in the same way nearly two decades ago.

Harvey (49) reported the effectiveness of tests and materials in discovering errors in arithmetic caused by failure to understand zero. Frederiksen and Satter (32) illustrated several methods of test construction and validation for arithmetic which are uniquely or rarely employed. Bouchard (10) explored effects of selected variables upon performance of sixth-grade children in arithmetic. Superior performance was generally achieved by children in the experimental groups (a) who were given the correct answers to arithmetic exercises after each exercise was completed, and (b) who knew that children in other sixth grades were being given the same tests.

Individual Differences

A common problem in the teaching of arithmetic is the provision of equal opportunity for all pupils in a classroom. From a study of a retarded group and a normal group of boys, Hamza (44) identified intellectual, emotional, social, environmental, and pedagogical factors as contributing to retardation. Hoel (54) reported a two-weeks' experiment in clinical procedures in arithmetic; efforts were made to discover specific arithmetic weaknesses and to determine at what stage in the child's development the difficulties arose. Holmes and Harvey (55) concluded that the method used in grouping arithmetic classes in order to deal with individual dif-

ferences was not of great importance; more crucial were the teacher's personal and professional qualities and methods of teaching.

Kliebhan (58) found that the principal differences between high and low achievers in problem solving were in ability to estimate answers and select steps in the process, and skill in fundamentals, computational ability, and quantitative understanding. No difference was found between attitudes of high and low achievers. Corle (18) found good problem-solvers superior to poor ones both in understanding of number relationships and in computation.

Another program for retarded children was described by Valentine (100), who found that they made four times as much progress in the special classrooms as could have been expected in a similar period of time under ordinary classroom conditions.

One of the most promising methods for dealing with individual differences, as described by Weaver (105), was differentiation of instruction. His summary of research findings should be of interest to those providing for individual differences in arithmetic instruction.

Aids to Learning

Thruout history, attention has been given to instructional aids. Adkins (1) described the use of physical devices thru the ages, giving particular attention to the tally, knotted cord, fingers, and abacus as means of recording, communicating, and computing with numbers. Edison (27) developed a 60-item test to be used in determining prospective teachers' understandings of the selection and use of such aids.

Fehr, McMeen, and Sobel (28) reported an experiment to measure the value of the use of computing machines in the learning of arithmetic; they found significant gains both in computation and reasoning on the part of the experimental group. Schott (90) showed that the abacus and adding machine were valuable tools for teaching arithmetic. Skinner (92) reported on the use of a mechanical device to provide controlled practice in developing skill in arithmetic.

Arithmetic Textbooks

Several studies were made of textbooks. Flournoy (30) examined six series published since 1950 and commented on the lack of agreement they showed regarding the teaching of higher-decade addition. Lee (62) analyzed the primary arithmetic textbooks of oriental countries and the United States, finding that instructional materials emphasized cultural as well as educational values. Harrison's investigation (46) dealt with semantic variation, ambiguity, and the introduction of new meanings as sources of difficulty. In a study of recently published arithmetic books, Glott (38) found that verbal matter in problem solving was more difficult

than that in developmental and explanatory material. There were also extreme variations within textbooks.

In a study of seven series of arithmetic textbooks for Grades III thru VI by Bhargava (9) there was found to be high agreement on the sequence of common steps, but the scope of each topic differed as did the amount of space allotted; there were also many differences regarding the use of larger numbers and fractions.

Hensell (50) reviewed existing studies and proposed criteria for the evaluation of problem-solving content in arithmetic textbooks.

Teacher Education

In assessing teacher understandings and attitudes, Phillips (78) found that prospective teachers' reactions to mathematics were a result of method of presentation, opportunities for achievement, teacher's personality, and type of problem solved. It was again observed that negative reactions started in the intermediate grades. Orleans and Sperling (75) and Orleans and Wandt (76) presented further evidence of difficulties in the arithmetical understandings of teachers. Dutton (25) found that isolation of attitude toward a subject was helpful in stimulating prospective teachers to overcome unfavorable attitudes and to strengthen favorable feeling. In another study Dutton (26) reported on attitudes of prospective teachers as determined by an objective evaluation instrument. Sueltz (97) studied the kinds of questions asked by prospective teachers and invited experimental studies to answer them.

Perhaps a knowledge of real mathematics would help more than method in overcoming fears of the subject. From a study of views held by selected leaders in mathematics education, Snader (93) found that a minimum of six semester hours should be provided for a mathematics course designed for elementary-school teachers of arithmetic. Layton (61) reported that only one-fourth of 85 institutions of higher learning preparing elementary-school teachers required mathematics for admission to a teacher-education curriculum. The mean mathematics content requirement of the four-year elementary curriculum was approximately 1.6 semester hours, as compared with means of 4.3 semester hours for art and for geography, and 11.5 semester hours for English. Schaaf (89) presented some evidence that elementary-school teachers did not understand mathematics and made recommendations for a course in arithmetic for teacher-education institutions. Weaver (104) also presented evidence of teachers' lack of understandings vital to meaningful arithmetic instruction in the elementary school, and identified the responsibility of teacher-education institutions to improve arithmetic scholarship. In providing for the mathematics education of elementary-school teachers, Hamilton (43) assessed the effectiveness of some experimental material designed to acquaint prospective teachers with the nature of the number system.

Future

As noted by Sherer (91), research in arithmetic has consisted mainly of brief cross-sectional investigations, inventories, short experimental studies, and test samplings of children's concepts, interests, abilities, and uses of arithmetic. Brown (12) predicted a new organization of arithmetic with basic skills presented earlier followed by practice where needed. Van Engen (102) noted implications of present knowledge for future trends in teaching arithmetic.

It is apparent from this review that research in arithmetic has changed from consideration of mechanics of computation to concern for problems of learning and concept formation. Future research might profitably be done by teams of teachers and experts in arithmetic working together to discover more about how children learn arithmetic.

Bibliography

1. ADKINS, JULIA E. *An Historical and Analytical Study of the Tally, the Knotted Cord, the Fingers, and the Abacus.* Doctor's thesis. Columbus: Ohio State University, 1956. 346 p. Abstract: *Dissertation Abstracts* 16: 2083; No. 11, 1956.
2. AFTRETH, ORVILLE B. "Brief Discussion of One of the Analyses in the Experiment: The Effect of the Systematic Analysis of Errors on Achievement in the Study of Fractions." *Journal of Experimental Education* 24: 273-81; June 1956.
3. AFTRETH, ORVILLE B. *The Effect of the Systematic Analysis of Errors on Achievement in the Study of Fractions at the Sixth Grade Level.* Doctor's thesis. Minneapolis: University of Minnesota, 1953. 351 p. Abstract: *Dissertation Abstracts* 14: 501-502; No. 3, 1954.
4. AFTRETH, ORVILLE B. "Shall We Expose Our Pupils to Errors?" *Arithmetic Teacher* 4: 129-31; April 1957.
5. BALDWIN, WILLIAM E. "Number Forms: A Common Type of Synesthesia." *Mathematics Teacher* 45: 510-12; November 1952.
6. BARAKAT, M. K. "Factors Underlying the Mathematical Abilities of Grammar School Pupils." *British Journal of Educational Psychology* 21: 239-40; November 1951.
7. BEBB, RANDALL R. *Comparison of Tachistoscopic Presentation with a Classroom Method of Teaching the Basic Multiplication Facts.* Doctor's thesis. Iowa City: State University of Iowa, 1952. 86 p. Abstract: *Dissertation Abtracts* 12: 693-94; No. 5, 1952.
8. BENZ, HARRY E. "Two-Digit Divisors Ending in 4, 5, or 6." *Arithmetic Teacher* 3: 187-91; November 1956.
9. BHARGAVA SUMITRA. *An Analysis and Comparison of the Scope and Sequence of the Computational Programs in Selected Arithmetic Textbooks.* Doctor's thesis. Syracuse: Syracuse University, 1956. 259 p. Abstract: *Dissertation Abstracts* 16: 1083-84; No. 6, 1956.
10. BOUCHARD, JOHN B. "An Exploratory Investigation of the Effect of Certain Selected Factors upon Performance of Sixth Grade Children in Arithmetic." *Journal of Experimental Education* 20: 105-12; September 1951.
11. BROOKE, GEORGE M. *The Common Denominator Method in the Division of Fractions.* Doctor's thesis. Iowa City: State University of Iowa, 1954. 140 p. Abstract: *Dissertation Abstracts* 14: 2290-91; No. 12, 1954.
12. BROWN, FRANCIS R. "Arithmetic—Friend or Foe?" *Arithmetic Teacher* 4: 1-9; February 1957.
13. BROWNELL, WILLIAM A. "Arithmetical Readiness as a Practical Classroom Concept." *Elementary School Journal* 52: 15-22; September 1951.

14. BROWNELL, WILLIAM A. "The Effects of Practicing a Complex Arithmetical Skill upon Proficiency in Its Constituent Skills." *Journal of Educational Psychology* 44: 65-81; February 1953.
15. BURCH, ROBERT L. "Formal Analysis as a Problem-Solving Procedure." *Journal of Education* 136: 44-47; November 1953.
16. BURCH, ROBERT L., and MOSER, HAROLD E. "The Teaching of Mathematics in Grades I Through VIII." *Review of Educational Research* 21: 290-304; October 1951.
17. BUSWELL, GUY T., and KERSH, BERT Y. *Patterns of Thinking in Solving Problems.* University of California Publications in Education, Vol. 12, No. 2. Berkeley: University of California Press, 1956. p. 63-148.
18. CORLE, CLYDE G. "The Characteristics of Procedures of Good and Poor Problem Solvers in Sixth Grade Arithmetic." *Abstracts of Graduate Theses in Education, 1944–1954.* Cincinnati: University of Cincinnati, Teachers College, 1955. p. 218-27.
19. CRUMLEY, RICHARD D. *A Comparison of Different Methods of Teaching Subtraction in the Third Grade.* Doctor's thesis. Chicago: University of Chicago, 1956. 115 p.
20. DAWSON, DAN T. "Number Grouping as a Function of Complexity." *Elementary School Journal* 54: 35-42; September 1953.
21. DAWSON, DAN T., and RUDDELL, ARDEN K. "The Case for the Meaning Theory in Teaching Arithmetic." *Elementary School Journal* 55: 393-99; March 1955.
22. DAWSON, DAN T., and RUDDELL, ARDEN K. "An Experimental Approach to the Division Idea." *Arithmetic Teacher* 2: 6-9; February 1955.
23. DEANS, EDWINA. "The Effect of Certain Immature Procedures on the Learning of Arithmetical Processes by Second Grade Children." *Abstracts of Graduate Theses in Education, 1944–1954.* Cincinnati: University of Cincinnati, Teachers College, 1955. p. 129-47.
24. DUTTON, WILBUR H. "Attitudes of Junior High School Pupils Toward Arithmetic." *School Review* 64: 18-22; January 1956.
25. DUTTON, WILBUR H. "Attitudes of Prospective Teachers Toward Arithmetic." *Elementary School Journal* 52: 84-90; October 1951.
26. DUTTON, WILBUR H. "Measuring Attitudes Toward Arithmetic." *Elementary School Journal* 55: 24-31; September 1954.
27. EDISON, WILLIAM P. *The Role of Instructional Aids in Arithmetic Education.* Doctor's thesis. Columbus: Ohio State University, 1956. 356 p. Abstract: *Dissertation Abstracts* 16: 2095-96; No. 11, 1956.
28. FEHR, HOWARD F.; MCMEEN, GEORGE; and SOBEL, MAX. "Using Hand-Operated Computing Machines in Learning Arithmetic." *Arithmetic Teacher* 3: 145-50; October 1956.
29. FLOURNOY, FRANCES. "A Consideration of the Ways Children Think When Performing Higher-Decade Addition." *Elementary School Journal* 57: 204-208; January 1957.
30. FLOURNOY, FRANCES. "The Controversy Regarding the Teaching of Higher-Decade Addition." *Arithmetic Teacher* 3: 170-73; October 1956.
31. FLOURNOY, FRANCES. "The Effectiveness of Instruction in Mental Arithmetic." *Elementary School Journal* 55: 148-53; November 1954.
32. FREDERIKSEN, NORMAN O., and SATTER, GEORGE A. "The Construction and Validation of an Arithmetical Computation Test." *Educational and Psychological Measurement* 13: 209-27; Summer 1953.
33. GIBB, E. GLENADINE. "Children's Thinking in the Process of Subtraction." *Journal of Experimental Education* 25: 71-80; September 1956.
34. GIBB, E. GLENADINE. "A Review of a Decade of Experimental Studies Which Compared Methods of Teaching Arithmetic." *Journal of Educational Research* 16: 603-608; April 1953.
35. GIBB, E. GLENADINE. "A Selected Bibliography of Research in the Teaching of Arithmetic." *Arithmetic Teacher* 1: 20-22; April 1954.
36. GIBB, E. GLENADINE. "Take-Away Is Not Enough!" *Arithmetic Teacher* 1: 7-10; April 1954.
37. GLENNON, VINCENT J., and HUNNICUTT, C. W. *What Does Research Say about Arithmetic?* Washington, D. C.: Association for Supervision and Curriculum Development, a department of the National Education Association, 1952. 45 p.

38. GLOTT, RALPH. *An Investigation of the Verbal Matter in Recently Published Arithmetic Textbooks and Workbooks for the Intermediate Grades.* Doctor's thesis. Pittsburgh, Pa.: University of Pittsburgh, 1955. 118 p. Abstract: *Dissertation Abstracts* 16: 477-78; No. 3, 1956.
39. GUNDERSON, AGNES G. "Arithmetic for Today's Six- and Seven-Year-Olds." *Arithmetic Teacher* 2: 95-101; November 1955.
40. GUNDERSON, AGNES G. "Thought-Patterns of Young Children in Learning Multiplication and Division." *Elementary School Journal* 55: 453-61; April 1955.
41. HALL, JACK V. "Business Uses of Mental Arithmetic in Ellensburg, Washington." *Journal of Educational Research* 46: 365-69; January 1953.
42. HALL, JACK V. "Mental Arithmetic: Misunderstood Terms and Meanings." *Elementary School Journal* 54: 349-53; February 1954.
43. HAMILTON, ELBERT W. *The Notational System as an Aid to Understanding Arithmetic.* Doctor's thesis. Iowa City: State University of Iowa, 1956. 193 p. Abstract: *Dissertation Abstracts* 16: 1849-50; No. 10, 1956.
44. HAMZA, MUKHTAR. "Retardation in Mathematics Amongst Grammar School Pupils." *British Journal of Educational Psychology* 22: 189-95; November 1952.
45. HANNUM, THOMAS E. "Identification and Measurement of the Arithmetical Concepts and Abilities of Pre-School and Primary Grade School Children." *Proceedings of the Iowa Academy of Science.* Ames: Iowa Academy of Science, Iowa State College, 1953. p. 514-18.
46. HARRISON, IRENE G. *Survey of Meanings of Words and Signs in Two Arithmetic Textbook Series.* Doctor's thesis. New York: Columbia University, 1953. 185 p. Abstract: *Dissertation Abstracts* 14: 64-65; No. 1, 1954.
47. HARTUNG, MAURICE L. "Estimating the Quotient in Division: A Critical Analysis of Research." *Arithmetic Teacher* 4: 100-11; April 1957.
48. HARTUNG, MAURICE L. "Selected References on Elementary School Instruction." *Elementary School Journal* 52: 162-64; November 1951. 53: 163-65; November 1952. 54: 163-65; November 1953. 55: 162-64; November 1954. 56: 124-25; November 1955. 57: 161-62; December 1956.
49. HARVEY, LOIS F. "Improving Arithmetic Skills by Testing and Reteaching." *Elementary School Journal* 53: 402-409; March 1953.
50. HENSELL, KENNETH C. *Children's Interests and the Content of Problems of Arithmetic.* Doctor's thesis. Stanford, Calif.: Stanford University, 1956. 186 p. Abstract: *Dissertation Abstracts* 16: 1857; No. 10, 1956.
51. HIGHTOWER, HOWARD W. "Effect of Instructional Procedures on Achievement in Fundamental Operations in Arithmetic." *Educational Administration and Supervision* 40: 336-48; October 1954.
52. HILL, EDWIN H. "Teachers! Two Kinds of Division." *Journal of Education* 137: 16-18; May 1955.
53. HIRSCH, MARTIN. "Does Changing the Form of a Problem Affect Its Difficulty?" *High Points* 33: 19-25; December 1951.
54. HOEL, LESTA. "Experiment in Clinical Procedures for Arithmetic." *Emerging Practices in Mathematics Education.* Twenty-Second Yearbook. Washington, D. C.: National Council of Teachers of Mathematics, a department of the National Education Association, 1954. p. 222-32.
55. HOLMES, DARRELL C., and HARVEY, LOIS F. "An Evaluation of Two Methods of Grouping." *Educational Research Bulletin* 35: 213-22; November 1956.
56. ILG, FRANCES L., and AMES, LOUISE B. "Developmental Trends in Arithmetic." *Journal of Genetic Psychology* 79: 3-28; September 1951.
57. JOHNSON, JOHN T. "Decimal Versus Common Fractions." *Arithmetic Teacher* 3: 201-203, 206; November 1956.
58. KLIEBHAN, MARY C. *An Experimental Study of Arithmetic Problem-Solving Ability of Sixth Grade Boys.* Washington, D. C.: Catholic University of America Press, 1955. 51 p.
59. LANKFORD, FRANCIS G., JR., and PATTISHALL, EVAN G., JR. *Development of Independence in Adding and Subtracting Fractions.* Charlottesville: University of Virginia, 1956. 69 p.
60. LANTON, WENDELL C. *Comparison of the Reading, Arithmetic, and Spelling Achievement of Third and Fifth Grade Pupils in 1953 and in 1934.* Doctor's thesis. Evanston: Northwestern University, 1954. 302 p. Abstract: *Dissertation Abstracts* 14: 1619-20; No. 10, 1954.

61. LAYTON, WILLIAM I. "Mathematical Training Prescribed by Teachers Colleges in the Preparation of Elementary Teachers." *Mathematics Teacher* 44: 551-56; December 1951.
62. LEE, SOOKNEY. *Primary Arithmetic Textbooks in Korea, Japan, China, and the United States.* Doctor's thesis. Iowa City: State University of Iowa, 1954. 401 p. Abstract: *Dissertation Abstracts* 14: 1584; No. 10, 1954.
63. LYNN, RICHARD. "Temperamental Characteristics Related to Disparity of Attainment in Reading and Arithmetic." *British Journal of Educational Psychology* 27: 62-67; February 1957.
64. MCALLISTER, BRIGID. "Arithmetical Concepts and the Ability To Do Arithmetic." *British Journal of Educational Psychology* 21: 155-56; June 1951.
65. MCKENZIE, HELEN M. "The Standardization of an Arithmetic-Mathematics Test in a Midland Area." *British Journal of Educational Psychology* 22: 73-74; February 1952.
66. MCLATCHY, JOSEPHINE H. "The Pre-School Child's Familiarity with Measurement." *Education* 71: 479-82; April 1951.
67. MARTIN, WILLIAM E. "Quantitative Expression in Young Children." *Genetic Psychology Monographs* 44: 147-219; November 1951.
68. MEDDLETON, IVOR G. "An Experimental Investigation into the Systematic Teaching of Number Combinations in Arithmetic." *British Journal of Educational Psychology* 26: 117-27; June 1956.
69. MILLER, G. H. "How Effective Is the Meaning Method?" *Arithmetic Teacher* 4: 45-49; March 1957.
70. MORTON, ROBERT L. *Teaching Arithmetic.* What Research Says to the Teacher, No. 2. Washington, D. C.: National Education Association, 1953. 33 p.
71. MOSER, HAROLD E. "Can We Teach Pupils To Distinguish the Measurement and Partition Ideas in Division?" *Mathematics Teacher* 45: 94-97; February 1952.
72. NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS. *Emerging Practices in Mathematics Education.* Twenty-Second Yearbook. Washington, D. C.: the Council, a department of the National Education Association, 1954. 434 p.
73. NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS. *The Learning of Mathematics, Its Theory and Practice.* Twenty-First Yearbook. Washington, D. C.: the Council, a department of the National Education Association, 1953. 335 p.
74. ORLEANS, JACOB S. "The Understanding of Arithmetic Processes and Concepts Possessed by Teachers of Arithmetic." Publication No. 12. New York: College of the City of New York, Division of Teacher Education, Office of Research and Evaluation, 1952. 59 p. (Mimeo.)
75. ORLEANS, JACOB S., and SPERLING, JULIA L. "Arithmetic Knowledge of Graduate Students." *Journal of Educational Research* 48: 177-86; November 1954.
76. ORLEANS, JACOB S., and WANDT, EDWIN. "The Understanding of Arithmetic Possessed by Teachers." *Elementary School Journal* 53: 501-507; May 1953.
77. PETTY, OLAN. "Non-Pencil-and-Paper Solution of Problems." *Arithmetic Teacher* 3: 229-35; December 1956.
78. PHILLIPS, CLARENCE. "Background and Mathematical Achievement of Elementary Education Students in Arithmetic for Teachers." *School Science and Mathematics* 53: 48-52; January 1953.
79. PHILLIPS, JOHN L., JR. "Perception in Number Skills; A Study in Tachistoscopic Training." *Journal of Educational Psychology* 45: 459-68; December 1954.
80. PIAGET, JEAN. "How Children Form Mathematical Concepts." *Scientific American* 189: 74-79; November 1953.
81. PIKAL, FRANCES. "Review of Research Related to the Teaching of Arithmetic in the Upper Elementary Grades." *School Science and Mathematics* 57: 41-47; January 1957.
82. PLANK, EMMA, and PLANK, ROBERT. "Emotional Components in Arithmetical Learning as Seen Through Autobiographies." *Psychoanalytic Study of the Child.* Vol. 9. (Edited by Anna Freud and others.) New York: International Universities Press, 1954. p. 274-96.
83. POFFENBERGER, THOMAS, and NORTON, DONALD A. "Factors Determining Attitudes Toward Arithmetic and Mathematics." *Arithmetic Teacher* 3: 113-16; April 1956.
84. PRATT, KARL C., and OTHERS. "Indeterminate Number Concepts: III. Representation by Children Through Selection of Appropriate Aggregations." *Journal of Genetic Psychology* 84: 39-63; March 1954.

85. PRIORE, ANGELA. "Achievement by Pupils Entering the First Grade." *Arithmetic Teacher* 4: 55-60; March 1957.
86. PURDY, CHARLES R., and KINNEY, LUCIEN B. "Directing Learning in Arithmetic." *Elementary School Journal* 54: 285-90; January 1954.
87. RHEINS, GLADYS B., and RHEINS, JOEL J. "A Comparison of Two Methods of Compound Subtraction." *Arithmetic Teacher* 2: 63-69; October 1955.
88. RIESS, ANITA P. "A New Rationale for the Teaching of Fractions." *Harvard Educational Review* 25: 105-25; Spring 1955.
89. SCHAAF, WILLIAM L. "Arithmetic for Arithmetic Teachers." *School Science and Mathematics* 53: 537-43; October 1953.
90. SCHOTT, ANDREW F. "Adventure in Arithmetic." *Instructional Materials for Elementary Schools.* Thirty-Fifth Yearbook. Washington, D. C.: Department of Elementary School Principals, National Education Association, 1956. p. 86-90.
91. SHERER, LORRAINE. "Some Implications from Research in Arithmetic." *Childhood Education* 29: 320-24; March 1953.
92. SKINNER, BURRHUS F. "The Science of Learning and the Art of Teaching." *Harvard Educational Review* 24: 86-97; Spring 1954.
93. SNADER, DANIEL. "Mathematical Background for Teachers of Arithmetic." *Arithmetic Teacher* 3: 59-65; March 1956.
94. SPITZER, HERBERT F., and FLOURNOY, FRANCES. "Developing Facility in Solving Verbal Problems." *Arithmetic Teacher* 3: 177-82; November 1956.
95. SPRINGER, DORIS V. "Development of Concepts Related to the Clock as Shown in Young Children's Drawings." *Journal of Genetic Psychology* 79: 47-54; September 1951.
96. STRUEVE, HELEN K. "Arithmetic via Television: I. A Report of the Pittsburgh Experiment." *Arithmetic Teacher* 3: 162-64; October 1956.
97. SUELTZ, BEN A. "Twenty-Five Questions on Arithmetic." *Arithmetic Teacher* 3: 250-51; December 1956.
98. THYNE, JAMES M. *Patterns of Error in the Addition Number Facts.* Scottish Council for Research in Education, Publications Series, No. 37. London: University of London Press, 1954. 270 p.
99. ULLRICH, ANNA. "Labeling Answers to Arithmetic Problems." *Arithmetic Teacher* 2: 148-53; December 1955.
100. VALENTINE, HUGH B. "Some Results of Remedial Education in a Child Guidance Center." *British Journal of Educational Psychology* 21: 145-49; June 1951.
101. VAN ENGEN, HENRY. "The Child's Introduction to Arithmetic Reasoning." *School Science and Mathematics* 55: 358-63; May 1955.
102. VAN ENGEN, HENRY. "Which Way Arithmetic?" *Arithmetic Teacher* 2: 131-40; December 1955.
103. VAN ENGEN, HENRY, and GIBB, E. GLENADINE. *General Mental Functions Associated with the Process of Division.* Cedar Falls: Iowa State Teachers College, 1956. 181 p.
104. WEAVER, J. FRED. "Crucial Problems in the Preparation of Elementary-School Teachers." *Elementary School Journal* 56: 255-61; February 1956.
105. WEAVER, J. FRED. "Differentiated Instruction in Arithmetic: An Overview and a Promising Trend." *Education* 74: 300-305; January 1954.
106. WEAVER, J. FRED. "Six Years of Research on Arithmetic Instruction: 1951-1956." *Arithmetic Teacher* 4: 89-99; April 1957.
107. WEAVER, J. FRED. "Whither Research on Compound Subtraction?" *Arithmetic Teacher* 3: 17-20; February 1956.
108. WILSON, GUY M. "Toward Perfect Scores in Arithmetic Fundamentals." *Arithmetic Teacher* 1: 13-17; December 1954.
109. WILSON, GUY M., and CASSELL, MABEL E. "A Research on Weights and Measures." *Journal of Educational Research* 46: 575-85; April 1953.
110. WOODS, ROBERT K. *Number Rearrangement as Arithmetical Learning.* Doctor's thesis. Iowa City: State University of Iowa, 1954. 250 p. Abstract: *Dissertation Abstracts* 14: 955; No. 6, 1954.
111. WRIGHTSTONE, J. WAYNE. "Constructing Tests of Mathematical Concepts for Young Children." *Arithmetic Teacher* 3: 81-84; April 1956.
112. WRIGHTSTONE, J. WAYNE. "Influence of Research on Instruction in Arithmetic." *Mathematics Teacher* 45: 187-92; March 1952.

CHAPTER III

Science in the Secondary Schools

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DURING the period under review, education in science and mathematics received an unprecedented amount of attention and support. As yet, however, the published research in science education does not reflect this fact to any great extent. While research has tended to become somewhat more sophisticated in design and analysis, the problems under consideration tend to be similar to those which have been examined over the last 20 years.

Science in General Education *

The inescapable reality that the children of this generation will live in a scientific world is reflected in much educational research. Research for many years has demonstrated the existence of an abiding conviction that citizens must be scientifically literate. Three major investigations were devoted to aspects of providing adequate general education in science.

Flannigan (15) undertook an investigation in which he sought to determine the present status of general-education science in the public high schools of the United States, Grades IX-XII. In a sample of schools an attempt was made to determine the place of general-education science, the methods used in teaching such courses, and the methods of selection of content, and to evaluate the objectives of general-education science in the schools in which such courses were taught. A second purpose of his investigation was to show how the general-education science courses compared in the above areas with the conventional science courses: general science, biology, elementary chemistry, and elementary physics as taught in selected schools.

An abbreviated statement of findings includes: (a) General-education courses, particularly those replacing chemistry and physics, were increasing in the public high schools. (b) Educators were increasingly prone to realize the value of general-education science for the nonscientist. (c) Most schools permitted general-education science courses to be counted toward a science major to fulfil graduation requirements. (d) Most of the education courses were developed for the junior and senior years, perhaps indicating some dissatisfaction with conventional chemistry and physics as they were taught for nonscientists. (e) Three out of four of the general-education courses studied included laboratory work. (f) Checklist data showed that more than 60 percent of the general-education courses were acceptable to colleges for entrance credit. (g) Principals preferred men teachers for general-education science courses. (h) Gen-

* The first part of this chapter was compiled by Herbert A. Smith.

eral-education science courses were not considered as courses for the slow learner. (i) The most generally accepted objective was to present a broad integrated understanding in science which should directly contribute to the scientific method and critical thinking. (j) The subjectmatter survey was still the most popular means of presenting general-education science material. (k) One of the commonest methods of selecting content for such courses was to choose a textbook which conformed closely to the objectives to be attained.

In another investigation, Burleson (10) developed an instrument and designed procedures which would assist school community groups to study and analyze the adequacy of their science program. Basically his study was an investigation of a curriculum revision process. Certain assumptions were made relative to the various aspects of curriculum planning. These included: (a) Curriculum change can best be accomplished thru orderly and planned means. (b) It is necessary to plan for the building of consensus concerning the characteristics of a particular school program. As a result of the study, certain recommendations were made. These included: (a) the need for further improvement and refinement of instruments and technics employed in the light of the experience gained; (b) the need to determine the degree to which success or failure of the procedures and instruments employed was directly dependent upon local leadership; and (c) the need to determine whether the procedures employed in this particular study were structured too highly or not highly enough.

Caldwell (11) reported a study closely paralleling the two well-known studies by Wise and Martin on principles of science important in physical and biological sciences respectively. Caldwell sought to identify the principles of the earth sciences which are significant for general education in the secondary school, together with the relative importance of these principles. In all, 332 principles of earth science were identified. Of these, only 36 were judged to be undesirable for inclusion in the science program in general education in the secondary school. It was also concluded that there was abundant material available for use in teaching the earth sciences.

Studies at the Junior High-School Level

Curriculum

In another study related to principles as objectives of science instruction, Smith (39) undertook to determine the relative importance of principles of science which are desirable for inclusion in a general-science course at the junior high-school level. Of the 302 principles considered, 253 were believed to be desirable for inclusion in general science. Of these principles, 141 were from physical-science areas and 112 were from biological-science areas. In a companion study, Smith (40) investigated the use of experiments in general-science courses at the junior high-school

level. A large number of the experiments available were judged to be suitable for use with the inductive method. In the opinion of the judges, most of the experiments could be performed with relatively simple apparatus. While the findings served to emphasize the importance of demonstration, more than half the experiments were deemed to be appropriate for individual work in the laboratory; the inference was that more individual laboratory work should be provided for general-science courses. It was suggested that further efforts should be made to locate and develop suitable experiments and demonstrations.

Kahn (22) attempted to determine the effect of teaching current events in science upon the development of the scientific attitudes of seventh- and eighth-grade boys. In both grades boys who had received training in the scientific attitude by means of the teaching technics suggested improved their scientific attitudes significantly more than comparable boys who did not receive this training. A majority of the pupils in the experimental groups at both grade levels said they were in favor of the procedure developed in this study; they were of the opinion that it caused a favorable change in either their way of thinking or in their way of behaving.

An investigation of the role of assumptions in ninth-grade general science was reported by Obourn (33). The ninth-grade general-science teachers observed were not particularly sensitive to assumptions and showed little awareness of the role of assumptions in their acceptance of conclusions. Obourn concluded that writers of instructional materials, teachers, and administrators needed to develop a clearer understanding of the significance and place of assumptions in the acceptance of conclusions.

In another investigation, Frasier (16) sought to improve instruction in junior high-school science. As a result of his investigation he concluded that seventh-grade pupils did not naturally have scientific attitudes nor did they know how to apply the scientific method. When specifically taught, satisfactory progress was made; this was especially true of the development and maintenance of scientific attitudes. The experimental group, whose instruction emphasized problem solving and scientific attitudes, did as well as the control group on knowledge of subjectmatter.

Kasling (23) prepared a reference book covering the general field of conservation of natural resources for use by junior high-school pupils. Appropriate criteria were established and applied in the selection of pupil activities, suggestions, pictures, illustrations, motion pictures, and the principles of science and social studies. In another study related to conservation, Brown (8) produced a resource unit for seventh-grade teachers dealing with conservation of natural resources. The unit included separate sections on mineral, soil, forest, water, and wildlife conservation.

History of Science in the Junior High School

Two studies were devoted to historical aspects of the development of general science in the junior high school. Blanc (4) traced developments

antecedent to the general-science course; he saw it resulting from various scientific and social forces at work during the preceding 300 years and as an outgrowth of the junior high-school movement. He suggested that general science incorporates the best practices from nature study in the elementary schools and from the specialized-science courses offered in senior high schools.

Haupt (21) traced the development of secondary-school science, especially in Grades VII, VIII, and IX, between 1920 and 1954. He concluded that there is less agreement as to the methods and purposes of science in education today than previously. He identified trends toward exploration, differentiation, socialization, and articulation, especially in the junior high school. He found more individual and social integration in recent years, with less emphasis on precollege and vocational preparation.

Evaluation

Reiner (37) cautioned against too literal interpretations of statistically significant differences. His analysis revealed the danger of bias in sampling and stressed the need for careful interpretation and analysis. Oleson (34) attempted to determine how well four types of objective tests evaluated the abilities of general-science students. It was found that all types of tests correlated fairly well with course grades; completion-type items showed the highest correlation.

Miscellaneous Studies

Adragna (2) undertook to determine the significance of certain variables both separately and in combination for the purpose of predicting achievement in junior high-school general science. No significant interactions were discovered; however, the variables of sex, arithmetic achievement, and grade placement were singly significant, and hence, were considered to have potential value as predictors of achievement in New York City junior high-school general science after the effects of initial science scores and mental ages had been eliminated.

Smith (41) conducted a study of trends in junior high-school general science. In the sample studied, all grades at the junior high-school level showed increases in number of periods a week, with the seventh grade showing the most gain and the ninth grade showing least. There was also some evidence that the time in minutes a period at each grade level had increased, again with the seventh grade showing the greatest amount of increase and the ninth grade the least. Gains in enrolment followed the same pattern.

Biology: Curriculum and Instructional Problems *

An analysis of principles and activities important to general-biology courses was made by McKibben (28). She (a) evaluated biological

* The remainder of the chapter was compiled by Nathan S. Washton. Thanks are due the members of the National Association for Research in Science Teaching for making this review possible.

principles for general education, (b) determined the relative value of learning activities and how they contribute to an understanding of these principles, and (c) indicated whether an activity should be performed as an individual laboratory activity or as a demonstration.

LeMaster (25) compared the contents of 12 city and state high-school biology syllabuses with recommendations made by experts. Many biology teachers replied to a questionnaire checklist which listed content. The findings established that several states were revising their courses of study; other states were using obsolete materials which needed modernizing.

Simon (38) outlined a philosophy of science education and considered its applications in biology teaching. Giovannangeli (17) was interested in determining the accuracy of certain concepts concerning the use and effects of alcoholic beverages. One hundred and ninety concepts were evaluated for accuracy by one jury, and another jury evaluated the importance of these concepts in the teaching of high-school biology. Only 18 concepts were judged as true and one as false by all jury members; it was thought that 139 concepts could be taught as "true" and 13 as "false"; the rest were to be taught as "debatable." This study gives rise to a series of other problems related to the degree of teaching for accuracy and the ability to learn science concepts at different levels of maturation.

Anderson, Montgomery, and Smith (3) examined the effectiveness of sound motion pictures in the teaching of biology. Using in part random selection, three groups of students were formed: (a) a control group in which no films were shown or in which teachers showed films of their own choice, (b) an experimental group in which students saw selected films during the school year, and (c) an experimental group in which the films were bolstered by emphasizing the principles stressed in each film. Analysis of variance and covariance provided some evidence that results in the third group described above were superior.

Chemistry: Curriculum and Instructional Problems

An attempt was made by Nelson (31) to evaluate the effect of sound motion pictures on the achievement of high-school chemistry students. A unit on sulfur was taught to two different groups; in one group no films were used, and in the second group several appropriate films were employed for teaching purposes. An analysis of covariance showed a significant difference in favor of the group to which films were shown.

Colyer and Anderson (12) compared two methods of teaching formula writing in chemistry: the traditional method (matching radicals mechanically) and the sequence method (diagramming the empirical formula). Four classes were taught by each method. The same books were used in three-fourths of the cases. An analysis of covariance showed a significant difference in favor of the experimental group which used the sequence method. On the basis of this study, it appears to be justifiable to spend

the additional time required to teach formula writing by an inductive approach.

A study pertaining to the development of improved demonstrations for teaching the principles of chemistry was made by Nichols (32). Four principles were selected, and demonstrations were catalogued according to these principles. Specific criteria and procedures were used in selecting the demonstrations. Thru the use of extensive laboratory work, critical comments were given for 27 demonstrations with reference to scientific principles, and suggestions were made for the improvement of three demonstrations and the development of five "new" ones.

Boeck (6) conducted an experimental study to compare the learning of students who were taught by the inductive-deductive approach versus the more conventional deductive-descriptive method. Classes were selected at random from schools in Minnesota, and experimental and control groups were set up to compare the two instructional procedures. Comparisons were made on the basis of the following four objectives: (a) knowledge of facts and principles of chemistry, (b) applications of the chemical principles to new situations, (c) knowledge of and the ability to use the scientific method with accompanying scientific attitude, and (d) ability to perform in the laboratory. For all the objectives, differences were observed in favor of the inductive-deductive class; statistically significant differences were revealed in knowledge of and ability to use scientific method and attitude, and in ability to identify proper laboratory procedures.

The variances arising from two approaches to the learning of high-school chemistry were investigated by Lucow (26). The two approaches were described as textbook-centered and laboratory-centered with the distinction being one of emphasis rather than abstraction. These teaching approaches were usually found in the Manitoba high schools where this experiment was conducted. The statistical analysis involved the testing for significance of differences between variances in which Model II analysis of variance was used to determine the components. The experiment was conducted individually for each of two groups: the "accelerated" (college preparatory) students and the "nonaccelerated" students who were not interested in university admission. The examination which was administered was divided equally among three objectives: (a) recall of basic concepts, (b) application of concepts and principles, and (c) comprehension and interpretation. Pretests and post-tests were employed, and increases in variances compared. The findings were: (a) "Accelerated" students increased in variance as a group regardless of approach, textbook, or laboratory. (b) The "nonaccelerated" students profited more from the laboratory approach insofar as increase in variance of the group was concerned. Lucow recommended that the laboratory approach be used for all students; his suggestion was based on the educational philosophy that great variation in classroom achievement is typical of accommodation to individual differences among students during the learning process.

Hadley, Scott, and Van Lente (20) examined the relationship between the grades received by 696 freshmen in college chemistry courses and the high-school grades those students had earned in chemistry, mathematics, and physics. College chemistry had been taught on the assumption that the students had no high-school chemistry. The investigators reported that students who had taken high-school chemistry, physics, and mathematics had the lowest percentage of "D" and "E" grades and the highest percentage of grades "A," "B," and "C." With or without high-school mathematics and physics, students who had high-school chemistry showed marked superiority over students who had not had the latter course. The best records in beginning college chemistry were made by students who had taken a combination of high-school chemistry, physics, and mathematics; the most frequent grade for these students in college chemistry was "B." No attempt was made to determine how much of the reported superiority was due to high-school instruction and how much was due to other factors.

Kercheval (24) studied the status of chemistry in Iowa high schools. Of the 850 school officials contacted by questionnaire, 390 responded; 251 of these schools offered no chemistry. The reasons for no instruction in chemistry were, in order of frequency: no community demand (55 percent), too expensive, lack of room, no qualified teacher, of insufficient value, and no time available in the curriculum.

Physics: Curriculum and Instructional Procedures

Brainerd (7) attempted to determine to what extent individual elements of the scientific method were to be found in physics laboratory workbooks and manuals for students in the introductory high-school physics course. The experiments in 12 high-school physics laboratory workbooks and manuals were listed in question form and checked by a specialist in science teaching for accuracy and suitability. Individual steps in the scientific method were checked for each of the experiments in the workbooks that were employed in the study. The author's findings were: (a) Most of the individual steps of the scientific method applicable in high-school physics experiments were included in the manuals, but not necessarily all steps in any one experiment. (b) The most serious omission was the need for repeating an experiment. (c) The manuals neglected to include a discussion of the scientific method and to point out clearly each step of the method as it occurred in the experiments.

Finch (14) made a study of simple projects which could be carried on in a high-school physics laboratory. He sent questionnaires to 400 physics teachers in New York State, received 200 replies, and reported the following findings: (a) In general, New York schools offering courses in physics allotted at least one period a week for laboratory work; 48 percent of those replying devoted two periods a week to laboratory work. (b) There was a considerable difference of opinion as to which experiments

were important. (c) Measurements of volume and density appeared to be most widely used. (d) Very few schools required students to perform exercises dealing with the tensile strength of solids.

Abrahamson (1) compared two methods of teaching elementary mechanics. Traditional teaching was employed in the control group, and experimental teaching thru discussion and use of visual aids was employed with a group of less able students of low socioeconomic status. Pretests and post-tests were administered to both groups. No reliable difference on the post-test or on a recall test given two months after the conclusion of the study was noted altho the control group was significantly better at the beginning. Significant gains were reported for the experimental group, and it appeared that the visual method was successful especially with the low-caliber group.

Curtis (13) studied the number and types of mathematical terms needed to explain principles of physics. She listed the mathematical terms which appeared in five textbooks in high-school physics and those principles of physics which appeared in at least three of the five books. The study suggested that students were required to have a knowledge of arithmetic, simple algebra, geometry, and the fundamentals of trigonometry in order to understand high-school physics textbooks. The greatest amount of mathematics was needed in the study of mechanics and the least in the study of atomic energy. The author recommended that mechanics be taught during the latter part of the course rather than at the beginning.

Integrated Courses in Physical Sciences

The status of integrated physical-science courses in senior high schools was investigated by Ray (36) who queried 100 secondary schools in cities of 5000 or more population in 24 states. Seventy schools responded. Forty of them offered a physical-science course, chiefly in Grades XI and XII, which integrated physics, chemistry, geology, meteorology, and astronomy. Findings showed an increase in such courses and in enrolments in them. The courses were usually substituted for the traditional chemistry or physics courses by students not planning to go to college.

Mudge (30) undertook a similar study altho it was less extensive. He concluded that the senior-science survey course was widespread and that attempts were made to gear the subject to the community and its youth. Consumer education was frequently emphasized; some courses appeared to be designed to occupy the uninterested student's time. The courses were comparatively new. Flannigan's findings (15) were much the same.

Glidden (18) investigated the teaching of soil and water conservation in secondary schools. He selected 66 principles which might be included in the school curriculum and had them evaluated by two groups of specialists. On the basis of a statistical analysis undesirable items were eliminated. An examination testing the remaining principles was administered

to seniors in selected high schools. Test scores were considered low, and curriculum changes were suggested to overcome the deficiencies.

Miles (29) contributed a useful study that should help the organization and teaching of a physical-science course on the high-school level. A large number of principles of physics, chemistry, and geology were found to be feasible objectives for courses in physical sciences, and many experiments already in use in high-school science courses were deemed adaptable for use in physical-science courses. This study as well as others indicated that individual laboratory experiences can be made suitable for the development of the understanding of basic principles of the physical sciences.

The Gifted or Talented Science Student

Chapter VII in this issue is devoted to studies dealing with gifted students, but a few of especial interest at the secondary level will be reviewed here.

Gordon (19) investigated methods of making provisions for outstanding science and mathematics students in selected high schools in California and Arizona. Questionnaires, expert judgments, visits, and contest results were used by the investigator. The author listed the following conclusions: (a) Superior students were victims of excessive demands on their time. (b) Ability grouping could be used in all types of schools. (c) Such grouping should be based on several criteria. (d) Science and mathematics departments could undertake their own programs for detecting and fostering superior students. (e) Mathematics teachers were less aware of the possibilities of providing for outstanding students than were science teachers. (f) Methods found to be most widely used by teachers and schools included in this study could be recommended for widespread use by all schools and teachers.

Using the case history approach, Bull (9) determined the activities and backgrounds of 100 high-school students identified by teachers as having dominant science interests. Major findings and conclusions were: (a) The large majority of these students were superior in scholastic ability to the other students in the same schools. (b) Three-fourths of the group studied had a preference for physical science. (c) Nearly all the students tended to have good social poise and were not classified as unusual in social behavior. (d) Approximately 60 percent of the students were inclined to avoid the usual physical activities found in the typical secondary school. (e) All members of the group were readers of science literature. (f) The students had been encouraged by parents or science teachers in their interests and hobbies.

Bloom (5) sought to determine why some high schools produced an unusually large number of Science Talent Search winners. Data were obtained concerning three New York City schools. The author concluded: (a) Proper selection and motivation do encourage students in science careers. (b) It is essential to identify early those students with above-

average capacities and scientific leanings. (c) High IQ is a desirable but not a determining factor. (d) The cooperation and sympathetic understanding of many teachers are necessary. (e) Manipulative laboratory skills, indoctrination into methods of science, and ability to observe and record are also important factors in the individual's development. (f) It is desirable to provide opportunities for exploration thru participation in extracurriculum activities such as science clubs.

To identify significant characteristics of superior science students, MacCurdy (27) developed an inquiry form which was submitted to juries for editing. The outstanding 600 students selected by the 1952 and 1953 Science Talent Search were administered this inquiry form, and the responses were contrasted with those from a group of average students. Comparisons were reported with respect to personality, attitudes, opinions, interests, high-school performance, and family background. The author indicated that science interests had been greatly influenced by science teachers.

Applications and Related Science Studies

Washton (42) sought to determine the applications of several biological principles to a generalization, concept, principle, or problem in the physical sciences, astronomy, chemistry, geology, or physics. He was also interested in obtaining a list of these generalizations or principles in the physical sciences which may be more familiar to students of biology and/or giving students useful concepts or items of knowledge from the physical sciences so that they may understand the biological principles. Thru the use of a questionnaire administered to 50 members of the National Association for Research in Science Teaching, applications of the biological sciences to the physical sciences were listed and tabulated. The findings listed a sample of five biological principles and their respective applications to eight concepts in the physical sciences.

A study dealing with the ability to apply scientific principles was conducted by Owens (35). His purposes were: (a) to examine the relationship between the ability to recognize scientific principles and the ability to apply them, and (b) to see if an experimental method of instruction would improve students' ability to apply scientific principles to new situations.

One hundred and eighty biology students and 116 chemistry students were assigned to experimental and control groups equated on age and IQ. The experimental groups were expected to determine applications of the data supplied and how these applications were related to a selected group of scientific principles. Tests of ability to recognize and apply scientific principles were administered. Results showed that the experimental groups scored higher on the ability to apply scientific principles. No difference was noted between the sexes in this respect.

In studying the association between the student's evaluation of science as a subject and his accomplishment after study, White (43) employed the *Cooperative General Achievement Test II—Natural Sciences* and the *A.C.E. Psychological Examination for High School Students.* Student reaction to the study of science was determined by a 30-item science-evaluation inventory. Three hundred and thirty-two Grade XII students from eight high schools were tested. Correlational and factorial procedures were employed in statistical analysis. White concluded: (a) Opinion of science as a study was a factor that was related to accomplishment and which operated in conjunction with mental ability. (b) On the same levels of mental ability, relative evaluation of science as a subject for study appeared to influence accomplishment correspondingly. (c) On the same level of science evaluation, accomplishment varied with level of mental ability.

Summary

The selection of the studies reviewed in this section was made from the following four issues of *Science Education:* February 1954, December 1954, December 1955, and December 1956. A number of studies were not reviewed because they dealt only with trends, were very limited in scope, employed inadequate sampling technics, or stressed opinions rather than evidence. Very likely some excellent studies were inadvertently omitted.

On the whole, there are too few research studies that emphasize the experimental approach for determining more effective instructional procedures in high-school science. Perhaps there should be a greater stress on cooperative or team research. Curriculum and teaching depend very heavily upon advances in psychology. Unfortunately, there is little reference to the latest studies in psychology or to the research work of scientists. There is also a fitting place for the case study and historical technics for research work in science education; such research seems to be lacking on the high-school level.

Most of the studies that were reviewed in this section could help high-school science teachers improve their instruction if they had access to them. It is very unfortunate that most of the high-school science teachers in America do not know of the existence of these research studies. Several agencies and professional associations should examine what can be done to help the high-school science teacher keep up to date on the latest research in the teaching of science.

Bibliography

1. ABRAHAMSON, BERNARD. "A Comparison of Two Methods of Teaching Mechanics in High School." *Science Education* 36: 96-106; March 1952.
2. ADRAGNA, C. MICHAEL. *Prediction of Achievement in Junior High School General Science.* Doctor's thesis. New York: New York University, 1954. 167 p. Abstract: *Dissertation Abstracts* 14: 2289; No. 12, 1954.

3. ANDERSON, KENNETH E.; MONTGOMERY, FRED S.; and SMITH, HERBERT F. A. "Toward a More Effective Use of Sound Motion Pictures in High School Biology." *Science Education* 40: 43-54; February 1956.
4. BLANC, SAM S. "The Development of Science Education in the Junior High School." *Science Education* 36: 107-13; March 1952.
5. BLOOM, SAMUEL W. "The Search for Science Talent." *Science Education* 38: 232-36; April 1954.
6. BOECK, CLARENCE H. "Teaching Chemistry for Scientific Method and Attitude Development." *Science Education* 37: 81-84; March 1953.
7. BRAINERD, ARTHUR B. *A Determination of the Extent to Which Individual Elements of the Scientific Method Are Found in High School Physics Laboratory Workbooks and Manuals.* Master's thesis. Boston, Mass.: Boston University, 1952. 97 p.
8. BROWN, DONALD G. *A Resource Unit on the Conservation of Natural Resources for the Course in Washington State History, Government, Industries, and Resources for the Seventh Grade of the Shumway Junior High School, Vancouver, Washington.* Master's thesis. Seattle: University of Washington, 1954. 374 p.
9. BULL, GALEN W. *The Activities and Backgrounds of Pupils with Dominant Science Interests.* Doctor's thesis. Columbia: University of Missouri, 1954. 366 p. Abstract: *Dissertation Abstracts* 15: 61; No. 1, 1955.
10. BURLESON, CHARLES E. *The Development of Procedures and Materials for Study and Revision of the Science Curriculum in Secondary Schools.* Doctor's thesis. Urbana: University of Illinois, 1954. 207 p. Abstract: *Dissertation Abstracts* 15: 61-62; No. 1, 1955.
11. CALDWELL, LOREN T. "Determination of Earth Science Principles Desirable for Inclusion in the Science Program of General Education in the Secondary School." *Science Education* 39: 196-213; April 1955.
12. COLYER, LUTHER M., and ANDERSON, KENNETH E. "A Comparison of Two Methods of Teaching Formula Writing in High School Chemistry." *School Science and Mathematics* 52: 50-59; January 1952.
13. CURTIS, CHARLOTTE. *A Determination of Mathematical Terms in Secondary School Physics Textbooks.* Master's thesis. Boston: Boston University, 1953.
14. FINCH, RAYMOND C. *A Study of the Methods of Conducting Physics Laboratory Work in Secondary Schools with Some Suggestions for Improvement by Means of Simple Research Projects.* Master's thesis. Ithaca, N. Y.: Cornell University, 1952. 92 p.
15. FLANNIGAN, NORMAN A. *A Study of High School Science Courses in Grades 9–12 Designed for General Education.* Doctor's thesis. Ithaca, N. Y.: Cornell University, 1954. 210 p. Abstract: *Dissertation Abstracts* 15: 62-63; No. 1, 1955.
16. FRASIER, JAMES E. *A Supervisory Program for the Improvement of Instruction in Certain Learning Activities of Junior High School Science.* Doctor's thesis. Greeley: Colorado State College of Education, 1954. 193 p.
17. GIOVANNANGELI, ARTHUR J. *The Selection, Development, and Objective Evaluation of Concepts in Alcohol Education as an Aid to Curriculum Construction.* Master's thesis. Boston: Boston University, 1954. 127 p.
18. GLIDDEN, HARLEY F. *The Identification and Evaluation of Principles of Soil and Water Conservation for Inclusion in the Secondary School Curriculum.* Doctor's thesis. Lincoln: University of Nebraska, 1953. 255 p. Abstract: *Dissertation Abstracts* 14: 615-16; No. 4, 1954.
19. GORDON, GARFORD G. *A Study of Methods of Making Provision for Outstanding Science and Mathematics Students in High Schools.* Doctor's thesis. Los Angeles: University of Southern California, 1952. 484 p.
20. HADLEY, E. H.; SCOTT, R. A.; and VAN LENTE, K. A. "The Relation of High School Preparation to College Chemistry Grades." *Journal of Chemical Education* 30: 311-13; June 1953.
21. HAUPT, WALTER N. *The Historical Background of Science Teaching in Junior High Schools Since 1920.* Master's thesis. Boston: Boston University, 1954.
22. KAHN, PAUL. *An Experimental Study To Determine the Effect of a Selected Procedure for Teaching the Scientific Attitudes to Seventh and Eighth Grade Boys Through the Use of Current Events in Science.* Doctor's thesis. New York: New York University, 1955. 167 p. Abstract: *Dissertation Abstracts* 15: 1767-68; No. 10, 1955.

23. KASLING, ROBERT W. *Cooperating with Nature; A Reference Book of the Conservation of Natural Resources Prepared for the Junior High School Level.* Doctor's thesis. New York: New York University, 1954. 415 p. Abstract: *Dissertation Abstracts* 15: 208-209; No. 1, 1955.
24. KERCHEVAL, JAMES W. "Why Is Chemistry Not Taught in More Schools?" *Journal of Chemical Education* 30: 497; October 1953.
25. LEMASTER, ROGER A. *A Content Analysis of Selected Biology Courses of Study.* Master's thesis. Muncie, Ind.: Ball State Teachers College, 1952. 36 p.
26. LUCOW, WILLIAM H. "Estimating Components of Variation in an Experimental Study of Learning." *Journal of Experimental Education* 22: 265-71; March 1954.
27. MACCURDY, ROBERT D. *Characteristics of Superior Science Students and Some Factors That Have Led to Their Development.* Doctor's thesis. Boston: Boston University, 1954. 141 p.
28. MCKIBBEN, MARGARET J. *An Analysis of Principles and Activities of Importance for General Biology Courses in High Schools.* Doctor's thesis. Pittsburgh, Pa.: University of Pittsburgh, 1953. 409 p. Abstract: *Dissertation Abstracts* 13: 1116; No. 6, 1953.
29. MILES, VADEN W. *A Determination of the Principles and Experiments Desirable for a High-School Course of Integrated Physical Science.* Ann Arbor, Mich.: Edwards Brothers, 1950. 430 p.
30. MUDGE, JOHN E. *The Feasibility in Present Usage of the Senior Advanced General Science Course in High School.* Master's thesis. Ithaca, N. Y.: Cornell University, 1952. 84 p.
31. NELSON, COURTENAY M. "Effectiveness of Sound Motion Pictures in Teaching a Unit on Sulfur in High School Chemistry." *School Science and Mathematics* 52: 8-10; January 1952.
32. NICHOLS, WILLIAM N. *New and Improved Demonstrations for Use in Teaching Scientific Principles in Chemistry.* Master's thesis. Boston: Boston University, 1950. 100 p.
33. OBOURN, ELLSWORTH S. "The Role of Assumptions in Ninth-Grade General Science." *Science Education* 40: 87-91; March 1956.
34. OLESON, LYLE. *Abilities of General Science Students with Respect to Four Objective Types of Tests.* Master's thesis. Muncie, Ind.: Ball State Teachers College, 1952. 156 p.
35. OWENS, J. HAROLD. "The Ability To Recognize and Apply Scientific Principles in New Situations: An Experimental Investigation in High School Biology and Chemistry." *Science Education* 35: 207-13; October 1951.
36. RAY, SISTER M. AMADEUS. *Nationwide Status of Integrated Courses in Physical Sciences.* Master's thesis. Boston: Boston University, 1953. 34 p.
37. REINER, WILLIAM B. "Test Items and Curriculum Background as Factors Which Influence Results in Evaluating Learning in High School General Science." *Science Education* 38: 139-42; March 1954.
38. SIMON, HARRY A. *A Basic Philosophy of Science Education and Its Application in Biology Teaching.* Master's thesis. Ithaca, N. Y.: Cornell University, 1953.
39. SMITH, HERBERT F. A. "A Determination of Experiments Desirable for a Course of General Science at the High School Level: I." *Science Education* 35: 279-84; December 1951.
40. SMITH, HERBERT F. A. "A Determination of Experiments Desirable for a Course of General Science at the Junior High School Level: II." *Science Education* 36: 32-47; February 1952.
41. SMITH, KEITH F. "Trends in Junior High School Science." *Science Teacher* 23: 86-88; March 1956.
42. WASHTON, NATHAN S. "Applying Biological Principles to Physical Sciences." *Science Education* 38: 136-39; March 1954.
43. WHITE, CHESTER R. *A Study of Approach-Avoidance Behavior in Relation to Scholastic Accomplishment in Natural Sciences Study.* Doctor's thesis. Pittsburgh, Pa.: University of Pittsburgh, 1953. 74 p.

CHAPTER IV

Mathematics in the Secondary Schools

LUCIEN B. KINNEY and MARY K. TULOCK

DURING the period 1951-1956 a number of articles of theoretical interest appeared which are certain to influence future research. In view of the relationship between conceptual thinking and subsequent research, a summary of theoretical points of view is useful to supplement reports of empirical studies.

Attitudes

Terrell (38) and Gough (16) summarized the factors influencing mathematical attitudes and made relevant recommendations. Poffenberger and Norton (30) asked 16 college freshmen what had influenced their attitudes toward arithmetic and mathematics. Parental attitudes, teachers, and school environment were identified as strong influencing factors. Malone and Freel (21) constructed an instrument to measure the attitudes of high-school students toward mathematics. They found that students generally realized its practical value.

Motivation

Symonds (37) pointed out that since a child learns only when he is motivated, it is important to recognize that the springs of human motivation revolve around the self concept. The fundamental psychological satisfaction, the need to be admired and approved, is met by acceptance and approval of the teacher. These are basic incentives to learning which the teacher can provide.

Methods

Berger (4, 5) illustrated several visual aids usable in high-school mathematics classes. Totten (39) verified the importance of clear understanding of words in algebra to facilitate learning. Van Engen (42) considered the failure of a mere memorization of words to develop the idea of function and pointed out the necessity for a carefully developed background of experience in which the function concept is brought into play. Seidel (35) charged the high-school mathematics teachers to challenge their students and to pile on enough homework to make them work hard and remember what they have learned. Parker (27) presented a collection of usable puzzles for the high-school classroom and stated their value in motivating the study of mathematics.

Beberman and Meserve (3), maintaining that graphing in high-school and college algebra has been interpreted too narrowly, offered suggestions for broadening the topic to include other ideas and emphasized the locus concept of plane geometry. These authors (2) also suggested that secondary-school teachers could, to good advantage, use "directed structuring" for discovery of a complex idea in mathematics. This general idea was expressed by Sobel (36) who tested an abstract, verbalized, deductive method with concepts defined and presented by the teacher, followed by practice exercises. This he compared with a concrete, nonverbalized inductive process by which students were guided thru experiments involving applications, discovery, and verbalized concepts. In two pairs of experimental and control groups the average IQ was 100 for one pair and between 110 and 115 for the other pair. He found no real difference between the final test scores made by groups taught under the two methods for the 100 IQ groups. In the higher IQ groups, however, there was a statistically significant difference in favor of the group taught by the inductive method. He concluded that brighter students profited in the learning of certain algebraic concepts and skills from an inductive, concrete, unverbalized method as opposed to the deductive method.

Peak (29) tested 3327 students enrolled in 129 classes in 119 schools for success in algebra learning. If 75 percent of a class was successful on an item, the class was considered successful. He found that only 3 percent of the classes could translate an equation into language. Students who could successfully analyze life problems ranged from 97 percent on a problem of buying steaks to 8 percent on a problem of income tax. Students could not use their knowledge of arithmetic in algebra, did not have clear concepts of symbols, could not estimate results, and could not organize solutions efficiently. Nielsen (25) reported that the major portion of time spent on mathematics in 60 Iowa high schools was devoted to lectures, blackboard demonstrations, and discussions centering around teacher demonstrations. The need for learning was not made apparent by the teacher, and with few exceptions no provision was made for individual differences.

Reeve (32) stated that mathematics has many applications that cannot be introduced into the classroom. This was clearly shown by the futile attempt to make geometry interesting by an overemphasis upon its application to tile floors, church windows, and the like a few years ago. He suggested that activities, such as playing store or organizing a bank, if carried to the extreme, may be worse than useless. He added that the right kinds of appreciation, attitudes, and ideals with respect to mathematics can be obtained only by artistic teaching.

Bernstein (6) in a Detroit high school gave individual instruction to small groups in 59 ninth-grade arithmetic classes. He attributed errors in arithmetic chiefly to misunderstanding the nature of the number system and to general personality factors. Eighty percent of the errors diagnosed fell into three categories: (a) the use of zero in multiplication and divi-

sion, (b) the borrowing process, and (c) the use of the decimal point. He considered individual instruction approximately twice as effective as class instruction; he reported that it required much less time, reduced emotional disturbances, and developed a greater liking for mathematics. Willerding (44) found that the cross-number puzzle was a good way to get basic review of the fundamental processes as well as to motivate the students, as classes eagerly tried original puzzles made by classmates to detect possible errors.

Randall (31), in the light of a study of errors, recommended that competence in arithmetic, mathematical thinking of the word problem type, and academic standards receive stress at the high-school level. Corman (9) investigated the effects of varying the amounts and kinds of information given to help with problem solving; he concluded that less explicit instruction may be just as effective as more directive guidance for the less able students, while more explicit instruction will probably be most helpful with the more able students. Schunert (34) found that boys exceeded girls in geometric achievement. He suggested that frequent reviews, differentiated assignments, study of life applications, and supervised study periods favored mathematics achievement of secondary-school students. Renner (33) concluded from a study of 40 Iowa high schools of different sizes that the level of functional competence which a student achieved was not affected by the size of the school.

Curriculum

Manheimer (22) suggested that teachers need a knowledge of digital computers in order to answer students' questions and for occupational guidance purposes. He pointed out that the digital computer has affected the market for mathematicians and threatens to refashion much of our modern world. He thought that mathematics teachers could play a vital part in these great new developments. Caton (8) proposed more emphasis from the elementary thru the college level on fundamental ideas and concepts, with more time spent on "why's."

Meserve (24) discussed the needs of high-school mathematics students and stated that more and more colleges were asking that the high schools be more thoro in the treatment of fundamental concepts. Wilson (45) suggested a new approach to better understanding of our own decimal number system by studying other number systems, pointing out that one drawback was the lack of junior and senior high-school teachers who were prepared to teach other systems. Payne (28) reported on 30 topics used for enrichment of high-school algebra for the gifted. Utz (40) described an abstract algebra course taught at the University of Virginia for high-school teachers who were master's degree candidates with forgotten mathematical skills. The course was built around the concepts of integral domain, field and group, arithmetic, and elementary algebra.

Nielsen (25) surveyed the status of the mathematics curriculum in the Iowa high schools. He visited 60 schools selected at random within four sizes of classes in each quarter of the state, interviewed 155 teachers, and observed 103 classes. He concluded that the curriculum was comparable to that in other states. He reported that high-school enrolments in mathematics had reached a peak in 1949 and declined steadily thereafter. Fifty-five percent of the students in the high schools in his study were in mathematics courses. A single textbook was usually the basis for a course altho some supplementary books were used. High schools offering general mathematics and elementary algebra in Grade IX tended to require remedial mathematics for poor students.

Van Deventer (41) developed a procedure for the study and revision of the mathematics curriculum in secondary schools. Assuming the necessity of involving members of the community in the process, he devised a guide and inventories useful in group discussions. Fehr (12) described the experimental program at the University of Illinois which he believed would be a force in converting a traditional college preparatory program to one modern in spirit and content. Hunter (18) questioned colleges and universities concerning prefreshman mathematics courses. Seventy-four percent of the 269 respondents offered such courses.

Beberman and Meserve (1) presented a theoretical description of the role of the literal number symbol based on experiences of the University of Illinois Committee on Secondary School Mathematics during the years 1951 to 1954. They illustrated the kinds of experiences that help students acquire understanding. Friede (15) administered two questionnaires to secondary-school students to test understanding of such concepts as zero, equality, relation, and identity. She found that some students had retained their naive and primitive childhood understanding of some of the concepts. The ability to abstract was found to improve with age. Daughtery (10) investigated the functions of the mathematics department head and concluded that supervisory activities, duties, and responsibilities were greater in number and importance than administrative ones. Hunter (18) surveyed prefreshman mathematics offered in college to help those deficient in mathematics.

Guidance

Manheimer (22) pointed out the opportunities for mathematicians, and the need for counselors to keep abreast of developments in mathematics. He suggested that some mathematical background was desirable for those responsible for curriculum guidance. Mallinson and others (20) confirmed this viewpoint in a survey of the background of guidance counselors; it appeared that fewer counselors were trained in the fields of mathematics and science than in certain other fields. Blick and Braman (7) listed counseling practices currently used prior to enrolment in plane geometry and in elementary algebra in secondary schools in Connecticut.

Enrolment

Mallinson and others (20) reported that, beyond all reasonable doubt, in the last 30 years enrolments and numbers of specialized courses in mathematics at the high-school level have decreased in terms of percentages and in some cases in actual numbers. Enrolments have increased both percentagewise and numerically in general courses such as general mathematics. A comparatively small percentage of students takes mathematics beyond Grade X. Martens (23) reported that students who had received all their education in one-teacher-per-grade town schools had higher achievement in arithmetic and other subjects, in relation to their mental ability, than did a comparable group of students who had received all their elementary education in one-room rural schools.

Teacher Education

Another aspect of the study by Mallinson and others (20) had to do with teacher preparation and credential requirements in a large number of colleges in the Northwest. He found considerable variation both in teacher-education programs and in certification requirements. Many states required 18 or more semester hours of college-course work in mathematics before a teacher was allowed to teach mathematics in an accredited high school. In another group of states a teacher could teach mathematics without having had any college mathematics if the course was assigned by the principal. It was recommended that a study be made of what constitutes a desirable program of mathematics for training teachers, and that when such a program is established, state certification requirements be changed accordingly. Schunert (34) investigated a population of 100 secondary schools selected by stratified-proportionate sampling from Minnesota's 522 public secondary schools. From statistical analysis of the data he concluded that the students of teachers graduating from universities and private colleges were superior in mathematics achievement to the students of teachers educated in teachers colleges. Orleans (26) in a study of 1044 teachers and prospective teachers concluded that but few relationships and concepts in arithmetic appeared to be understood by a large percentage of teachers.

Textbooks

King (19) found that the dominant aim of authors of mathematics textbooks published before 1900 was mental discipline achieved thru memorization and rule application. At least 12 different teaching and learning aids were used by the authors and teachers, including answers, tables, notes, tables of contents, prefaces, and introduction. Nielsen (25) found few changes in mathematics textbooks, with the exception of general mathematics, over a 25-year period in 60 Iowa high schools.

Gifted Children

The gifted child has received considerable attention in recent years, both in research and in theoretical publications. Fehr (14) suggested that the biggest failing in education is in the identification and development of the gifted child in mathematics. He pointed out that gifted children need advanced and modern instruction in mathematics, yet many high-school teachers know little about the kind of mathematics program brilliant children should follow and less about modern mathematics. Fehr suggested in-service programs on the identification and teaching of the gifted. Hildreth (17) called attention to a number of points to be considered in coordinating a program for the gifted. Payne (28) found in a study of 30 topics considered suitable for enriching high-school algebra for the gifted, that bright students were more interested in ideas than in getting the answer by conceptualization, and preferred for extra work topics complete within themselves rather than sequential topics. It seemed hardly possible to provide too much enrichment. Students who attained greatest success evidenced no signs of overwork or of reaching a learning ceiling. Watson (43) in reporting on the School and College Study of the Ford Foundation stated eight views relative to the training of high-level ability persons in the fields of science and mathematics. The study undertook to enrich the educational experiences of the students of high academic ability while at the same time lessening the total time requisite for completion of high-school and college work.

Trends

Egloff (11) along with many others cited the increasing demands for mathematicians in other fields and their use in the statistical evaluation of laboratory data, in the development of machines and chemicals, and in market research. He noted the greater financial support of education at the undergraduate level by industry, grants for summer research by college teachers, and the planned exchange of personnel between colleges and industries.

Fehr (13) reported the trends in mathematics as reviewed at the Congress of the International Mathematics Union in Amsterdam, The Netherlands, September 1954, attended by more than 1700 delegates. In most countries attention to methods of teaching was indicated by replacement of lecture-study methods by methods of rediscovery thru problem solving and intuitive thinking.

Fehr (12) found that the number of high schools offering courses in analytic geometry and calculus continued to increase. Many first-year students with the requisite score on mathematics college entrance examinations saved time in college by receiving credit for the college mathematics taken in high school. Increased numbers of less able students were enrolled in nonacademic courses in mathematics, and more and better text-

books were available for these students. Classes in mathematics dealt with ideas and thinking as well as drilling on skills. Fehr listed the proposed projects for investigation by the International Commission on Mathematical Instruction during the years 1955-56: (a) producing treatises for secondary-school and junior-college teachers to help them in the proper teaching of modern mathematics, (b) in every country a continued study of the present and possible changes in mathematics education of those aged 16 to 21, and (c) a continued study of the role of mathematics and mathematicians.

Bibliography

1. BEBERMAN, MAX, and MESERVE, BRUCE E. "The Concept of a Literal Number Symbol." *Mathematics Teacher* 48: 198-202; April 1955.
2. BEBERMAN, MAX, and MESERVE, BRUCE E. "An Exploratory Approach to Solving Equations." *Mathematics Teacher* 49: 15-18; January 1956.
3. BEBERMAN, MAX, and MESERVE, BRUCE E. "Graphing in Elementary Algebra." *Mathematics Teacher* 49: 260-66; April 1956.
4. BERGER, EMIL J. "A Model for Visualizing the Formula for the Area of a Circle." *Mathematics Teacher* 48: 245-46; April 1955.
5. BERGER, EMIL J. "A Model for Visualizing the Pythagorean Theorem." *Mathematics Teacher* 48: 246-47; April 1955.
6. BERNSTEIN, ALLEN L. *A Study of Remedial Arithmetic Conducted with Ninth Grade Students.* Doctor's thesis. Detroit, Mich.: Wayne University, 1955. 265 p. Abstract: *Dissertation Abstracts* 15: 1567-68; No. 9, 1953.
7. BLICK, DAVID J., and BRAMAN, SHIRLEY E. "Some Practices Used in Counseling Students Prior to Enrollment in Elementary Algebra and Plane Geometry." *School Science and Mathematics* 54: 107-15; February 1954.
8. CATON, WILLIS B. "The Teaching of Mathematics." *School Science and Mathematics* 54: 490-92; June 1954.
9. CORMAN, BERNARD R. *The Effects of Varying Amounts and Kinds of Information as Guidance in Problem Solving.* Doctor's thesis. New York: Columbia University, 1954. 117 p. Abstract: *Dissertation Abstracts* 14: 1176-77; No. 8, 1954.
10. DAUGHTERY, JOSEPH D. *The Function of the Mathematics Department Head in a Large Urban High School.* Doctor's thesis. New York: Columbia University, 1954. 490 p. Abstract: *Dissertation Abstracts* 14: 785-86; No. 5, 1954.
11. EGLOFF, GUSTAV. "The Impact of Industry on Science." *School Science and Mathematics* 54: 101-106; February 1954.
12. FEHR, HOWARD F. "The Goal Is Mathematics for All." *School Science and Mathematics* 56: 109-20; February 1956.
13. FEHR, HOWARD F. "The International Mathematics Union, the International Congress of Mathematicians and the International Commission of Mathematical Instruction." *Mathematics Teacher* 48: 267-69; April 1955.
14. FEHR, HOWARD F. "Mathematics Instruction and Scientific Manpower." *School Science and Mathematics* 54: 169-72; March 1954.
15. FRIEDE, KARMI. *Abstraction and Concept Formation in the Field of Secondary School Mathematics.* Doctor's thesis. New York: Columbia University, 1954. 229 p. Abstract: *Dissertation Abstracts* 14: 1347-48; No. 9, 1954.
16. GOUGH, SISTER MARY FIDES. "Mathemaphobia, Causes and Treatment." *Clearing House* 28: 290-94; January 1954.
17. HILDRETH, GERTRUDE H. "School-Wide Planning for the Gifted." *Educational Administration and Supervision* 41: 1-10; January 1955.
18. HUNTER, LOUISE S. *Pre-Freshman Mathematics in State Colleges and Universities.* Doctor's thesis. Charlottesville: University of Virginia, 1953. 264 p. Abstract: *Dissertation Abstracts* 14: 1051-52; No. 7, 1954.

19. KING, ANGIE T. *An Analysis of Early Algebra Textbooks Used in American Secondary Schools Before 1900.* Doctor's thesis. Pittsburgh, Pa.: University of Pittsburgh, 1955. 222 p. Abstract: *Dissertation Abstracts* 15: 746-47; No. 5, 1955.
20. MALLINSON, GEORGE G., and OTHERS. "Final Report to the Central Association of Science and Mathematics Teachers of Its Committee on the Significance of Mathematics and Science in Education." *School Science and Mathematics* 54: 119-43; February 1954.
21. MALONE, WILLIAM H., and FREEL, EUGENE L. "A Preliminary Study of the Group Attitudes of Junior and Senior High School Students Towards Mathematics." *Journal of Educational Research* 47: 599-608; April 1954.
22. MANHEIMER, WALLACE. "The Digital Computer—A Challenge to Mathematics Teachers." *School Science and Mathematics* 54: 701-706; December 1954.
23. MARTENS, CLARENCE C. "Educational Achievements of Eighth-Grade Pupils in One-Room Rural and Graded Town Schools." *Elementary School Journal* 54: 523-25; May 1954.
24. MESERVE, BRUCE E. "Are the Colleges and the High Schools Cooperating Most Effectively in Meeting the Mathematical Needs of Their Students?" *School Science and Mathematics* 54: 299-302; April 1954.
25. NIELSEN, ROSS A. *Mathematics Instruction in Iowa High Schools.* Doctor's thesis. Iowa City: State University of Iowa, 1955. 286 p. Abstract: *Dissertation Abstracts* 15: 2490; No. 12, 1955.
26. ORLEANS, JACOB S. *The Understanding of Arithmetic Processes and Concepts Possessed by Teachers of Arithmetic.* Office of Research and Evaluation, Publication No. 12. New York: College of the City of New York, 1952. 59 p.
27. PARKER, JEAN. "The Use of Puzzles in Teaching Mathematics." *Mathematics Teacher* 48: 218-27; April 1955.
28. PAYNE, JOSEPH N. *Enrichment Topics for First and Second Course Algebra for Bright Pupils.* Doctor's thesis. Charlottesville: University of Virginia, 1955. 618 p. Abstract: *Dissertation Abstracts* 15: 2491-92; No. 12, 1955.
29. PEAK, PHILIP. *Efficiency in First Year Algebra.* Doctor's thesis. Bloomington: Indiana University, 1955. 131 p. Abstract: *Dissertation Abstracts* 15: 1574-75; No. 9, 1955.
30. POFFENBERGER, THOMAS M., and NORTON, DONALD A. "Factors Determining Attitudes Toward Arithmetic and Mathematics." *Arithmetic Teacher* 3: 113-16; April 1956.
31. RANDALL, ROGERS E. "Common Errors Made in General Mathematics by High School Students of Louisiana." *Mathematics Teacher* 48: 228-31; April 1955.
32. REEVE, WILLIAM D. "The Play of the Imagination in Mathematics." *School Science and Mathematics* 54: 463-70; June 1954.
33. RENNER, JOHN W. *Relationships Between Instructional Provisions and Functional Competence in Mathematics of Iowa High School Seniors.* Doctor's thesis. Iowa City: State University of Iowa, 1955. 141 p. Abstract: *Dissertation Abstracts* 15: 1188; No. 7, 1955.
34. SCHUNERT, JIM R. "The Association of Mathematical Achievement with Certain Factors Resident in the Teacher, in the Teaching, in the Pupil, and in the School." *Journal of Experimental Education* 19: 219-38; March 1951.
35. SEIDEL, GEORGE R. "Mathematics; A Language." *Mathematics Teacher* 48: 214-17; April 1955.
36. SOBEL, MAX A. *A Comparison of Two Methods of Teaching Certain Topics in Ninth Grade Algebra.* Doctor's thesis. New York: Columbia University, 1954. 101 p. Abstract: *Dissertation Abstracts* 14: 1647; No. 10, 1954.
37. SYMONDS, PERCIVAL M. "What Education Has To Learn from Psychology." *Teachers College Record* 56: 277-85; February 1955.
38. TERRELL, ANN. "I Cannot Learn Mathematics." *Peabody Journal of Education* 31: 335-36; May 1954.
39. TOTTEN, W. FRED. "Words as a Basic Factor in Understanding Algebra." *School Science and Mathematics* 56: 230-33; March 1956.
40. UTZ, WINFIELD R. "Algebra in the Training of Teachers." *School Science and Mathematics* 54: 10-12; January 1954.
41. VAN DEVENTER, LESTER R. *The Development of a Procedure for Study and Revision of the Mathematics Curriculum in Secondary Schools.* Doctor's thesis. Urbana: University of Illinois, 1954. 250 p. Abstract: *Dissertation Abstracts* 14: 800-801; No. 5, 1954.

42. VAN ENGEN, HENRY. "Words! Words! Words!" *Mathematics Teacher* 48: 81; February 1955.
43. WATSON, BERNARD B. "The AAAS Cooperative Committee on the Teaching of Science and Mathematics." *School Science and Mathematics* 54: 116-18; February 1954.
44. WILLERDING, MARGARET F. "Review of the Fundamental Processes; The Cross Number Puzzle." *School Science and Mathematics* 54: 51-52; January 1954.
45. WILSON, JACK D. "Staking Out New Ground in High School Arithmetic." *School Science and Mathematics* 54: 257-66; April 1954.

CHAPTER V

The Academic and Professional Preparation of Teachers of Science

GEORGE G. MALLINSON and JACQUELINE V. MALLINSON

A SHORTAGE of qualified science teachers has influenced both scientists and educators to write voluminously concerning the causes of the problem and its possible solutions. Nearly every journal contains articles that suggest ways in which the consequences of these shortages may be avoided. Some of the proposals are inherently sound; others are questionable.

Above and beyond all these suggestions, however, one finds that many investigators have been attacking the problem thru research. These investigations have dealt with (a) the academic and professional preparations of science teachers and (b) the implications of research findings for increasing the quantity and improving the quality of the science teachers.

Viewpoints of Administrators

The dilemma and the role of the school administrator with respect to the shortage of science teachers were recognized by several investigations. Three major studies were undertaken in order to elicit the views of the administrators about the situation and to determine what their needs might be. The Michigan Science Teachers Association polled one-half the school administrators in Michigan (23). Ming (29) carried out his study with the principals and superintendents of rural central schools of New York State listed in the *Directory of Central School Districts, 1950-51*. Nelson (30) investigated the status of science teaching in Illinois. In all three studies questionnaires were sent to school administrators for answers to three basic problems: (a) the types and numbers of positions in science teaching that were available, (b) the kinds and amounts of academic preparation that were desired in science teachers, and (c) the competencies other than academic preparation that science teachers needed.

The findings of all these studies were substantially the same. There were not enough science teachers to staff the positions that were available in the public schools of these states. Hence, in many cases teachers with major interests in areas other than science were often assigned to teach science classes. Further, the administrators pointed out that in nearly all schools teachers were expected to teach general-education sciences as well as courses in the specialized sciences. The common teaching combinations included general biology and general science; chemistry, physics, and general science; and chemistry, physics, general biology, and general science.

Hence, a teacher intensively trained in one field of science, with little or no training in others, was not so suitable as one with a broad training in many fields of science even if that training was not so intensive. It was pointed out, also, that at least a minimal level of training in mathematics was desirable because nearly all science courses had some mathematical content, and many science teachers also taught mathematics.

In general, nearly all the commonly accepted pedagogical characteristics were deemed essential for these teachers. Such characteristics included the ability to deal with different levels of ability among students in the same classroom, an understanding of child growth and development, and the ability to use all types of technics in motivating students to learn science. However, one general inference may be drawn concerning all suggestions for professional preparation. The science teacher should have the skill to use all mediums, that is, films, projects, field trips, and demonstrations, so as to enrich the science courses beyond the boundaries of the textbook. The training in methodology should, therefore, enable the teacher to keep the science course up to date.

Background and Competencies of Science Teachers

In view of the breadth of training desired by administrators for science teachers one might assume that colleges would be preparing teachers of science at all levels to meet the needs implicit in the views of the administrators. Such did not seem to be true for teachers being trained for the elementary and secondary levels.

Only one investigation was undertaken recently with respect to the education of teachers of elementary science. Mallinson and Sturm (26) undertook a study in which they analyzed the science backgrounds of prospective elementary-school teachers, administered tests to evaluate their subjectmatter competencies in science, and sought their opinions about their science training.

Most of the elementary-school teachers professed that they avoided science courses both in high school and in college when it was possible. In high school more of them enrolled in chemistry than in other sciences altho in college most of them enrolled in biology. The science courses in which they enrolled in college were ordinarily introductory courses designed for persons intending to enter scientific careers. The vast majority stated that they would have preferred to have enrolled in "broad field courses in science" had they been available. Nevertheless, nearly all of them believed that their backgrounds in science were sufficient to assure their competence to teach science in the elementary school. Yet, as a group, they fell well below the norms for high-school students on tests of general science. Their professed adequacy was, therefore, in doubt.

During the past five years there were many status studies that attempted to analyze the backgrounds of high-school science teachers. Most of them attempted to measure the subjectmatter knowledge of these teachers and

to determine the extent to which their backgrounds were suited to enable them to teach science in the typical high school. Among such studies were those by DeLoach and Hall (10, 11), Mallinson (21), Mallinson and Buck (24), Mallinson and Sams (25), and Warren (35). The investigations involved the use of interviews, questionnaires, and documentary analyses. Their conclusions tend to substantiate one another.

In general, teachers entering, as well as those in, the profession of science teaching were less well trained in the physical sciences than in the biological sciences. While many took the introductory courses in the physical sciences, only a small number pursued the area as far as completing a minor. Hence, most teachers of general science had extensive training in biological science but little in the physical sciences. This situation was anomalous in that more than two-thirds of the content of general science comes from the physical-science areas.

However, it may be generalized that science teachers tended to specialize in one area of science without regard for breadth of training in other areas. Further, when given tests of science designed for high-school students, the high-school teachers were not able to translate their college training into satisfactory answers to the questions.

The findings of a study by Watson and Victor (38) of 52 "converted" science teachers in Massachusetts emphasized the implications of the studies above. They found that science courses were frequently assigned to teachers who were trained in areas other than science, had no interest in science teaching, hoped to return to teaching in their major fields, but who were likely to remain in science teaching at least part time because of the shortage of science teachers. There was no evidence that, as a group, such teachers had any intention of improving their backgrounds to teach science thru inservice education. They did, however, desire assistance from qualified "supervisors."

In summary these studies suggested that the shortage of science teachers was severe. Further, those who were qualified to teach science did not generally have the breadth of training that seemed to be needed. The inservice assistance that they sought was not readily available.

Certification Requirements

Two studies were undertaken, one by Pruitt (31) and the other by Mallinson (22), to determine the relationship between certification requirements and the subjectmatter training of science teachers. Their analyses of certification codes revealed some interesting facts. In general, there was a lack of uniformity among the states with respect to the number of hours of subjectmatter required for certification to teach science. This situation raised problems when teachers transferred from one state to another. While most states did demand that teachers take a minimal number of hours of science to teach a field of science, seldom

did they require the breadth of training in several areas of science that seemed to be desirable. The situation was most unfortunate with respect to the teaching of general science in the junior high school. Most states allowed teachers who were certified to teach in the high school to teach any subjectmatter area in the junior high school. Because of the shortage of high-school science teachers, a great number of teachers of general science were those whose training fell in other areas. Yet, they were legally certificated to teach science.

The problem was further complicated by the fact that most of the states issued "special certificates" to teachers in "hardship" cases. If a school could not find a qualified science teacher, a person acceptable to the board of education without academic or professional training was assigned to teach a science course. The shortage of science teachers made such cases the rule in many areas.

Subjectmatter Courses for Science Teachers

A new development in college science courses was the appearance of basic science courses, survey courses, or science courses for general education. In general, they were integrated courses in either the biological or the physical sciences. Occasionally a course covering both the biological and the physical sciences was offered by a college. The studies indicate efforts by research workers to identify the desirable aims of such courses and the activities that would help attain these aims. While these courses were not designed specifically for teachers, they were found most frequently in institutions training teachers. In fact, research dealing with subjectmatter experiences for teachers invariably involved such courses.

Bullington (8), Goins (16), and Wilson (41) sought to determine the status of such courses in various colleges and universities of the United States. Their data were obtained thru questionnaires, checklists, and the evaluation of course syllabuses. They found that such courses were more likely to be offered in teachers colleges and state colleges than in universities. Further, in most institutions the program of study was developed by the faculty teaching such courses. However, there seemed to be no general agreement as to the specific aims of these courses or the persons for whom they were designed. Most colleges accepted such courses for transfer but seldom applied them toward majors or minors in the sciences. Generally, they seemed to be designed as terminal courses for nonscience majors or as general courses for prospective science teachers to acquaint them with the relationships among the various sciences.

Andrews and Breukelman (2), Dietrich (12), McWhirter (20), Washton (36, 37), and Winier (42) investigated the desirable content for survey courses in the biological sciences. Usually the content was organized around either the major principles of biological science of importance for general education or around biological problems of social significance. In many institutions the students participated in the selection of the major

areas of content to be covered. The studies pointed out that no suitable method was found for evaluating the outcomes of such courses. Generally the traditional type of objective test seemed to be used most widely.

Blanchet (7), Franks (14), and Randall (32) investigated the selection of subjectmatter content for survey courses in physical science. These studies polled the students to determine the questions in physical science to which they desired answers, and the areas in which they believed they needed the greatest amount of training.

The findings showed that teachers and nonscience majors preferred the survey courses in physical science to the introductory courses for the specialized sciences. The students seemed to favor courses in which astronomy, meteorology, earth science, chemistry, and physics were integrated under broad problems rather than courses in which these fields of science were compartmentalized.

However, the findings also revealed that students and teachers wanted the subjectmatter content to be flexible in order to meet the individual differences among the various classes of students.

Arnold (3) sought to identify certain criteria for selecting content for a general education college chemistry course. The criteria he identified were similar to those for selecting content for the survey courses in biological and physical science. However, he found that greater emphasis was placed on the continuity of experiences than was the case in the studies involving the survey courses.

Lewis (19) investigated the effectiveness of the college science sequences required in certain Northeastern teachers colleges for developing problem-solving skills in teachers. Weaver (39) sought to identify criteria for the selection of laboratory experiences for integrated physical-science courses for elementary-school teachers. Many of their conclusions are not pertinent here. However, their emphasis on the role of problem-solving skills as outcomes in courses of science for training teachers was significant.

Balcziak (4) compared the relative merits of demonstrations, combined demonstrations and individual laboratory work, and the individual laboratory method in physical-science courses for general education. Kruglak and Carlson (18) undertook a similar study for the field of physics. Both studies found that students gained significantly by all methods altho no one method seemed to be consistently superior to any other. However, the individual method seemed to produce significantly greater increments in achievement in those characteristics especially important for teachers, in particular in the ability to understand the "practical" types of laboratory exercises and the development of scientific attitudes.

Rankin (33) attempted to identify by means of questionnaires the competencies desired in teachers of the general-education sciences. The results indicated that teachers of courses in general-education science should (a) be broadly trained under the supervision of workers in general education rather than by specialists in science, (b) be able to explain

facts and principles from all areas of science in ways understandable to nonscience majors, and (c) be able to utilize scientific publications to keep their teaching up to date.

In summary, survey courses in the general-education sciences have grown rapidly in recent years altho there is no general agreement with respect to their specific aims or purposes. They are found most frequently in teachers colleges and state colleges where the majority of teachers are educated. Hence, one might infer that providing the breadth expected of teachers of science is a major function of such courses. Further, there seems to be a desire to provide teachers with academic courses that place greater emphasis on the outcomes of critical thinking and problem solving than do the traditional subjectmatter offerings in science.

Professional Preparation for Science Teachers

Many studies dealing directly with the professional preparation of science teachers were undertaken during the period reviewed. Subjects dealt with tended to fall into three categories, namely, (a) contents of methods courses in science, (b) student-teaching experiences, and (c) inservice training programs.

Chamberlain (9) and Walsh (34) investigated various aspects of contents of methods courses. Some of the studies dealt with surveys of the kinds of activities actually included in methods courses; others dealt with the content thought to be desirable by teachers, administrators, and educators.

These studies showed that nearly all institutions training science teachers offered courses in science methods for teaching science at both the elementary and secondary levels. All courses for elementary-school teachers involved all areas of science, while a greater number of special methods courses (i.e., teaching of physics) were offered for secondary-school teachers. However, the majority of such courses at the secondary level were general in nature.

In the elementary methods courses in science much emphasis was placed on the study of the subjectmatter of value for elementary-school teachers. The methods courses in science for secondary-school teachers, however, dealt chiefly with technics of teaching science. High-school teachers and college teachers differed greatly with respect to the emphasis thought appropriate in such courses. The high-school teachers emphasized the need for understanding teacher-pupil relationships in the classroom, evaluation, and philosophy of science education. The college educators tended to emphasize materials of instruction, methods of teaching, and curriculum content. All groups surveyed, however, were in accord with respect to the desirability of having students learn to prepare their own demonstration materials, utilize community resources effectively, and carry out successful field trips.

Beck (5) and Gifford (15) investigated the function of the program of student teaching in the professional preparation of science teachers. Their efforts centered around identifying the superior policies and practices for the program of student teaching for prospective science teachers and the changes that take place during the experience. Their data were obtained from questionnaires, interviews, conferences, observations, and weekly reports of the student teachers, and tests of various types given the prospective science teachers.

They found that college and university staff members should devote more time to the supervision of student teaching since there was little coordination between the academic training and the internship. Students and faculty both believe that more opportunity should be available for student teaching and more exacting requirements should be established for admission to the student-teaching program.

The suggestion that student teachers be assigned to regular public schools for the internship, and the fact that the prospective teachers were given much freedom in their assignments, both warranted a continuity, integration, and supervision of practice teaching not usually available.

Unfortunately, there is no substantial objective evidence to show that significant changes are made in students as a result of student-teaching experiences altho such changes are professed. The latter findings suggest the need for better means for evaluating the student-teaching experiences of the prospective science teacher.

Allen (1) compared the advantages and disadvantages of direct observation of classroom teaching by television with classroom visitation. Students and teachers observed activities by means of a closed-circuit television network and then discussed their observations. In general, the TV experiment was not successful. It was difficult for the "teaching" teacher, the camera and crew were distracting to the students, and mobility in the room was affected. Hence, this technic did not seem to be a suitable substitute for the classroom visitation.

These studies tended to point out the rather serious need for better cooperation among teachers and students in integrating the various facets of the programs for educating science teachers.

Bingham (6) and Droullard (13) investigated desirable activities for the inservice education of science teachers and the prevalence of inservice programs in the schools respectively.

Their findings revealed that many science teachers could profit from well-organized inservice programs since many were assigned to teach fields of science in which their backgrounds were meager and/or out of date. Yet, only about 6 percent of the schools offered opportunities for inservice experiences.

Bingham (6) presented a limited amount of evidence that supported the workshop technic as a popular means for inservice education. However, the technic seemed to have most approval when the inservice activities were planned at least to some extent by the participants.

The studies in this area are not sufficiently extensive, however, to warrant generalized conclusions. It is clear that this area is in need of much more study.

Enrichment of Science Teaching

Gustafson (17) and Wedul (40) investigated the place of conservation in the science program of the public school and the place of conservation in the education of science teachers. Their data were obtained by interviews, questionnaires, and the examination of college catalogs. Their findings revealed that few public schools offered conservation as a separate subject, despite the fact that conservation courses were offered in many colleges. Rather, conservation was integrated with courses in science and/or social studies, or was combined with the recreational and nature study activities that were part of the growing camping program in schools. The training program for science teachers may need to be modified to include conservation as an enrichment activity that permeates all science teaching.

Mason and Warrington (27) and Mecay (28) examined current scientific articles in journals and newspapers to determine the areas dealt with and to ascertain implications for teaching critical thinking. Mecay (28) restricted his study to articles in the field of genetics. Many of the findings were in areas peripheral to this report. It was noted, however, that popular publications contained many materials that were scientific in nature, that could be understood easily by the layman, and that could be used to teach critical thinking. The latter is, of course, a fundamental aim of all science teaching.

It may be concluded, therefore, that prospective science teachers should be taught to select and evaluate from among the vast array of published materials, those that offer possibilities for enrichment or which contribute directly to the attainment of the major objectives of science teaching.

Summary

The studies here reviewed suggest a few recommendations:

1. Some extensive work is needed to determine the exact nature of the academic courses in science valuable to prospective science teachers. Efforts should then be made to implement the findings.

2. There is a distinct need to ascertain the relative emphasis which should be given to the various parts of the curriculum designed to prepare science teachers; namely, academic preparation, professional preparation, student teaching, and inservice training. The supervision of all these parts should then be a cooperative enterprise among those who contribute their efforts to them.

3. Research is necessary to determine how a constant flow of qualified science teachers can be maintained to meet the needs of the public schools.

Bibliography

1. ALLEN, WILLIAM H. "Testing TV for Teacher Training at the University of Wisconsin." *Educational Screen* 32: 389-90; November 1953.
2. ANDREWS, THEODORE F., and BREUKELMAN, JOHN. "Biology Requirements in the General Education Programs of Some Midwestern Colleges and Universities." *Science Education* 37: 205-10; April 1953.
3. ARNOLD, LUTHER A. "The Development of a General Education College Chemistry Course." *Science Education* 40: 123-27; March 1956.
4. BALCZIAK, LOUIS W. *The Role of the Laboratory and Demonstration in College Physical Science in Achieving the Objectives of General Education.* Doctor's thesis. Minneapolis: University of Minnesota, 1953. 183 p. Abstract: *Dissertation Abstracts* 14: 502-503; No. 3, 1954.
5. BECK, RALPH L. *Planning a Student Teaching Program for Prospective High School Science Teachers.* Doctor's thesis. New York: New York University, 1954. 174 p. Abstract: *Dissertation Abstracts* 14: 303-304; No. 2, 1954.
6. BINGHAM, NELSON E. "Workshop for Science Teachers." *Science Education* 35: 177-84; April 1951.
7. BLANCHET, WALDO W. E. "Increased Pupil Responsibility for Planning Learning Experiences." *Science Education* 35: 187-88; October 1951.
8. BULLINGTON, ROBERT A. "The Subject-Matter Content of General Education Science Courses." *Science Education* 36: 285-97; December 1952.
9. CHAMBERLAIN, WILLIAM D. *Development and Status of Teacher Education in the Field of Science for the Elementary School.* Doctor's thesis. Detroit, Mich.: Wayne University, 1955. 205 p. Abstract: *Dissertation Abstracts* 15: 533-34; No. 4, 1955.
10. DELOACH, WILL S., and HALL, AUBURN R. "Time and Place of Undergraduate Training of a Group of High School Chemistry Teachers." *Science Education* 36: 90-91; March 1952.
11. DELOACH, WILL S., and HALL, AUBURN R. "The Undergraduate Preparation of High School Chemistry Teachers, Alabama, 1948-1949." *Science Education* 36: 27-28; February 1952.
12. DIETRICH, MARY A. *A Suggested Course of Study for Introductory College Biology, with an Emphasis on the Study of Living Material.* Doctor's thesis. Ithaca, N. Y.: Cornell University, 1953. 173 p.
13. DROULLARD, CLAYTON A. *The Pre-Service and In-Service Science Education of Iowa Secondary School Science Teachers.* Doctor's thesis. Boulder: University of Colorado, 1954. 144 p.
14. FRANKS, CLEVELAND J. *The Organization, Installation, Implementation, and Administration of a Course in Physical Science Designed for General Education.* Doctor's thesis. New York: Teachers College, Columbia University, 1953. 212 p.
15. GIFFORD, ROBERT W. *A Description of Certain Changes Accompanying Practice Teaching and Concomitant Experience.* Doctor's thesis. New York: Teachers College, Columbia University, 1956. 197 p.
16. GOINS, WILLIAM F., JR. "An Evaluation of Science Courses Offered for General Education in Selected Negro Colleges." *Science Education* 36: 248-49; October 1952.
17. GUSTAFSON, JOHN A. *A Study of Those Extra-Curricular Activities Which Contribute to Nature and Conservation Education in Certain Liberal Arts Colleges.* Doctor's thesis. Ithaca, N. Y.: Cornell University, 1954. 491 p. Abstract: *Dissertation Abstracts* 15: 63-64; No. 1, 1955.
18. KRUGLAK, HAYM, and CARLSON, CARL R. "Performance Tests in Physics at the University of Minnesota." *Science Education* 37: 108-21; March 1953.
19. LEWIS, JUNE E. *An Investigation of the Effectiveness of the Science Sequence in Certain Teachers Colleges.* Doctor's thesis. Cambridge, Mass.: Harvard University, 1953. 227 p.
20. MCWHIRTER, NOLAN. *The Status of General Biology in the General Education Program of Colleges and Universities in Arizona, Colorado, Kansas, Nebraska, New Mexico, Oklahoma, and Texas.* Doctor's thesis. Greeley: Colorado State College of Education, 1953. 95 p.
21. MALLINSON, GEORGE G. "Investigation of the Subject-Matter Backgrounds of Student Teachers in Science." *School Science and Mathematics* 49: 265-72; April 1949.

22. MALLINSON, GEORGE G. "State Requirements for Certifying Teachers of High-School Science." *School Science and Mathematics* 51: 543-56; October 1951.
23. MALLINSON, GEORGE G. "The Status of Science Teaching in Michigan." *Newsletter of the Michigan Science Teachers Association* 3: 1-14; June 1955.
24. MALLINSON, GEORGE G., and BUCK, JACQUELINE V. "Comparison of the Characteristics of Positions in Science Teaching with the Characteristics of Teachers Being Trained." *High School Journal* 38: 17-22; October 1954.
25. MALLINSON, GEORGE G., and SAMS, CONWAY C. *A Comparison of the Knowledges of Physical Science with Those of Biological Science of College Students.* Paper presented to the National Association for Research in Science Teaching, Chicago, Illinois, April 12, 1956. Kalamazoo: Western Michigan University, 1956. 7 p. (Mimeo.)
26. MALLINSON, GEORGE G., and STURM, HAROLD E. "The Science Backgrounds and Competencies of Students Preparing To Teach in the Elementary School." *Science Education* 39: 398-405; December 1955.
27. MASON, JOHN M., and WARRINGTON, WILLARD G. "An Experiment in Using Current Scientific Articles in Classroom Teaching." *Science Education* 38: 299-304; October 1954.
28. MECAY, LEROY E. *Heredity in Non-Technical Magazines as a Basis for Genetics in General Education for Teachers.* Doctor's thesis. Columbia: University of Missouri, 1956. 210 p.
29. MING, ROGER W. "A Survey of the Opinions Held by Administrators of Rural Central Schools Concerning the Preparation of Secondary School Science Teachers." *School Science and Mathematics* 52: 607-13; November 1952.
30. NELSON, T. A. "What Administrators Want in the Training of Science Teachers and the Actual Training of Beginning Science Teachers in the State of Illinois." *Science Education* 40: 24-43; February 1956.
31. PRUITT, CLARENCE M. "Certification Requirements for Teachers in Elementary and Secondary Schools." *Science Education* 36: 182-93; April 1952.
32. RANDALL, ROGERS E. "A Basis for a Physical Science Course on the College Level." *Science Education* 37: 211-12; April 1953.
33. RANKIN, OREN R. "A Study of Competencies Desirable for Instructors of College General Education Courses in Physical Science." *Science Education* 36: 297-306; December 1952.
34. WALSH, WILLIAM J., JR. *The Status of the Science Methods Course for Secondary Teaching in Selected State Colleges and Universities in the United States.* Doctor's thesis. Boulder: University of Colorado, 1954. 274 p.
35. WARREN, PERCY H. "The Education of High School Science Teachers at Madison College." *Science Education* 38: 164-66; March 1954.
36. WASHTON, NATHAN S. "A Syllabus in Biology for General Education, II." *Science Education* 36: 227-37; October 1952.
37. WASHTON, NATHAN S. "Teaching Biology for General Education." *Science Education* 36: 237-40; October 1952.
38. WATSON, FLETCHER G., and VICTOR, EDWARD. *The Converted Science Teacher.* Cambridge, Mass.: New England School Development Council, 1957. 22 p.
39. WEAVER, ALLEN D. *A Determination of Criteria for Selection of Laboratory Experiences Suitable for an Integrated Course in Physical Science Designed for the Education of Elementary School Teachers.* Doctor's thesis. New York: New York University, 1956. 377 p.
40. WEDUL, MELVIN O. *Conservation Education in Selected Minnesota Elementary Schools and State Teachers Colleges.* Doctor's thesis. Boulder: University of Colorado, 1956. 179 p.
41. WILSON, LELAND L. "General Education Science in Southern Association Junior and Senior Colleges." *Science Education* 36: 293-97; December 1952.
42. WINIER, LEONARD P. "Biological Science in the General Education Program at Iowa State Teachers College." *Science Education* 38: 28-39; February 1954.

CHAPTER VI

College Mathematics and Teacher Education

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THE increased number of studies pertaining to the placement and preparation of college students, the college mathematics curriculum (traditional and general-education courses and special programs), and the training of teachers (elementary and secondary) have led to the establishment of a separate chapter in this area. The readily available sources cited most frequently in this report are *Mathematics Teacher, School Science and Mathematics,* and *American Mathematical Monthly.* Also cited are *Arithmetic Teacher, Elementary School Journal, Journal of Educational Research,* and *Educational Record.* Except for *American Mathematical Monthly,* each of these is indexed in the *Education Index.*

An increasingly important source is *Dissertation Abstracts,* published by University Microfilms (Ann Arbor, Michigan), which contains 600-word abstracts of doctoral dissertations completed in many universities. It is now being combined with the listing by title in *Dissertations Accepted by American Colleges and Universities,* published by the H. W. Wilson Company. Separate listings of studies in mathematics education have been published in recent years by the U. S. Office of Education (6). Some of these and other pertinent summaries of research by Brown (7) and Kinsella (34) have appeared in *Mathematics Teacher.*

The increasing demand for college education for American youth and the contemporary ferment in elementary college mathematics courses have provided a fertile ground for studies of related problems. Experimentation is common; methods of evaluation are being sought. This is illustrated by the Survey of Research Potential and Training in the Mathematical Sciences which was instituted in 1955 by the National Research Council with the support of the National Science Foundation. The report (59) of the Subcommittee on Undergraduate Colleges mentioned several experimental college programs and included a preliminary report of the survey (22). Questionnaire replies were received from 1700 (68.5 percent) of the people who had received doctorates in mathematics in the period 1915-1954. A preliminary analysis indicated that the returns were fairly representative of the different areas of employment. Implications for college teaching are evident from the following facts: (a) 1050 of the 1700 decided on a career in mathematics while they were in college; (b) the same number gave their liking for mathematics as the principal reason for their choice of a career; (c) 486 had changed their majors from another subject to mathematics; and (d) 1431 mentioned inspiring undergraduate teachers that they had had.

Preparation and Placement

The problem of the poorly prepared student in elementary college mathematics has continued to engage the attention of researchers. Williams (65) made a survey of college programs for the poorly prepared student in mathematics. He sent out 500 questionnaires and received replies from institutions in 46 states with student bodies ranging from 150 to 19,000. The number of replies received was not stated. The survey showed that administrators of college-mathematics courses thought that about one-half of the students taking college algebra or trigonometry were either poorly prepared or totally unprepared. Of the institutions which replied, 62 percent offered remedial courses in algebra, and 61 percent of these gave credit for such courses. Eighty-eight percent of the responses seemed to indicate that the best permanent solution to the problem is for the high schools to teach fewer topics and to teach them more thoroly. The investigator called for closer cooperation between secondary schools and colleges.

Hunter (29) considered prefreshman college courses provided for poorly prepared students. She studied the status of such courses in 269 state colleges and universities and found at least one such course in 74 percent of the institutions. Placement tests and admission units were the most commonly used bases for assignment of students to such classes. Fifty-eight percent of the schools offered some such course for college credit. Kinzer and Kinzer (35) did a follow-up study on 89 students who had been required to take a noncredit algebra course at Ohio State University before taking college algebra. They found that those who did poorly in the noncredit course seldom went beyond college algebra and that those who did continue made relatively poor marks in the advanced courses.

Seigle (53) reported on a study of the prediction of success in college mathematics at Washburn University over a period of five years. The relative prognostic values of the *Washburn Entrance Mathematics Test*, high-school grade average, number of units of high-school mathematics, *American Council on Education Psychological Examination*, and an English test, and combinations of these instruments were compared. Multiple correlations were used to measure the prognosis of success in college algebra, trigonometry, analytic geometry, and calculus. In the case of the latter two courses, prognoses were made both before and after any college mathematics had been taken. The highest correlation obtained was .82 which occurred in two instances: (a) between grades in algebra and a battery of evaluative instruments, and (b) between grades in calculus and a battery of evaluative instruments.

Childs (11) compared the achievement in mathematics of freshmen students who completed certain high-school mathematics courses by correspondence study with the University of Nebraska Extension Division and later enrolled at the University, with that of students who had no

correspondence experience in high school. There was a significant difference in favor of the correspondence group, but the investigator cautioned that this did not imply that the correspondence method of instruction was necessarily superior.

Wolfe (67) reported on an investigation of the final trigonometry grades of students who differed with respect to lapse of time since completion of their last preceding mathematics course. He found the failure rate to be significantly higher and the mean grade to be significantly lower for a group which had only a summer vacation lapse while the members of the other group had lapses of 8 to 17 months. It is interesting that on a pretest there was a significant difference in favor of the close-proximity group. The researcher suggested that the contrast between these results appeared to have implications in the use of pretests to obtain matched groups for experimental studies.

Habel (23) made a study of 27 college algebra texts to determine their coverage of certain arithmetic fractions and radicals deemed essential to the study of trigonometry. Filano (20) reported on an experiment to determine the extent to which college freshmen can understand a particular topic of analytic geometry from reading the textbook independently. One group of students studied the unit on the hyperbola independently while proceeding with other work, and the other group had the usual class discussion of this unit. The difference on testing was in favor of the independent group but was not statistically significant. The investigator pointed out the similarity of the content to the previous unit on the ellipse.

College Programs

Studies of college programs in mathematics were made from an historical point of view and as surveys of contemporary offerings. Wahlert (63) conducted an historical investigation of objectives, content, and achievement of objectives in elementary college mathematics from 1636 to 1952. Altho limited to material covered in freshman courses in American colleges, the curriculum scope was quite broad. The study characterized 1636-1876 as a tradition-forming era, 1876-1914 as an interval of stabilization and extension of instruction to higher mathematics, and 1914 to 1952 as a period of rapid growth with new forces affecting elementary college instruction. The study included an analysis of popular textbooks of the various periods.

Read and Klein (49) investigated the uniformity of mathematics courses and of requirements for a mathematics major in the colleges of the United States. Information was obtained from the catalogs of 98 colleges representing 87 percent of a 10-percent sample of the appropriate institutions listed in the *Education Directory*. Additional information was obtained from some of the colleges. The number of courses offered ranged from zero to 91 with a mean of 16. The most common requirement for a major was approximately 24 semester hours, and the range was from 12 to 48.

All courses listed under the same titles were analyzed for uniformity of content and the results tabulated. The diversity of offerings under a specified title appeared commensurate with the diversity of requirements.

Cameron (10) reported on a personal tour he made of mathematics departments in 33 American colleges and universities under a Ford Foundation grant. He collected information about mathematics courses for general education, various types of freshman courses, analytic geometry and calculus courses, modern algebra and other upper-division courses, and teacher-education courses. He concluded that many of the small colleges maintained a higher quality of undergraduate instruction than did the larger universities.

Programs for General Education

The general education values of mathematics were listed by Abernethy (1) as: (a) basic factual information and skills that make it a key to other knowledge, (b) aid in personal adjustment, (c) experience in logical thought, (d) esthetic value, and (e) aid in understanding the cultural heritage.

Beenken's committee (3) made a questionnaire survey of the practices of 110 colleges in giving a course in "College Mathematics for General Education," a course not planned for engineers, scientists, or even modern social scientists. Sixty-seven of the 110 colleges offered such a course, and 16 others expressed a desire to do so. Most of the students had had two years of high-school mathematics. Thirty-three texts and six manuscripts were in use. Credit given varied from 2 to 10 semester hours. Most of the courses were required or were among a group of courses satisfying a college requirement. The committee obtained considerable information regarding these courses and concluded that: (a) no single course met the needs of all students and instructors; (b) it was important to consider the instructor as well as the students in preparing a course; and (c) the choice of topics was not as important as the attitudes of the teacher and the students. The committee made several recommendations for courses and topics. It was believed that the Duren committee's *Universal Mathematics* (60, 61) required a higher level of preparation than Beenken's committee assumed. However, it was agreed that students interested in technical mathematics (for natural science, social science, or the arts) could all be served by a single course, not necessarily traditional.

Cogan (12) summarized several types of survey courses for liberal arts students and discussed the texts available for such courses. Haggard (24) synthesized 23 research studies which reported the mathematics used in areas pertinent to the general-college student. He then compared this synthesis with the content of 19 college-level cultural general mathematics textbooks. He found the former to be quite elementary in comparison with the latter. He recommended a test based on the common

topics and a special course for students found deficient by the test. Woodby (68) compiled a list of subjectmatter items from terminal courses in mathematics at the junior-college level and evaluated them on their worth for general education. His use of a jury of specialists was characteristic of several recent studies.

Bentz (4) studied critical mathematics requirements for community-college programs. He used questionnaires, personal interviews, and observations to collect descriptions of 237 situations in which mathematics was used or needed. The areas of mathematics most frequently found were fundamental processes of arithmetic, the use of formulas, problem solving, mechanical calculating aids, and analysis of data.

Rasmussen (48) made a study of mathematical skills and concepts desirable as preparation for study in courses at the University of Kansas for students who were not majoring in mathematics or the physical sciences. He did not include advanced courses of a specialized or technical nature in other departments. The study included the schools of business, education, journalism, and pharmacy, and the departments of astronomy, bacteriology, chemistry, geography, home economics, psychology, physical science, and physics in the school of liberal arts. A tabulation was made of the mathematical topics found in the texts used in courses which were considered to involve the use of some mathematics. A similar tabulation was made from interviews with the instructors of these courses. The results based upon interviews differed somewhat from the results of the textbook analysis. The majority of the mathematics topics needed were found to be quite elementary, but a majority of the students did not possess sufficient arithmetical maturity to enable them to benefit properly from many of the university courses. A need for understanding of elementary statistical concepts was also found in many courses.

Abernethy (1) reported on an experimental course in mathematics for general education. Each student progressed at his individual pace, and it was believed that considerable progress was made in the field of personal adjustment. Class time was spent on mathematics; nontechnical aspects were developed by the students independently, using outside readings as evidenced by 16 300-word written or oral reports.

Rogers (50) described the development of a general education course in pure mathematics given at Harvard University to students more than half of whom had had no college mathematics. The course was intended to explain the spirit and method of modern pure mathematics. Kline (36) reported on his experimental freshman course for liberal arts students seeking to develop an appreciation of the role of mathematics in Western culture. Ayre (2) summarized the results of some research on junior-college mathematics and discussed the feasibility of a single course to meet the needs of both general education and the training of future specialists. He pointed out that only 20 to 25 percent of junior-college students proceeded into senior college and that many junior colleges could not offer separate courses for the two groups.

Experimentation with educational television became increasingly popular, but research reports on such experiments were still scarce. Jones (30) presented a series of seven weekly telecasts on number concepts for adults. Brune (8) reported on a television course he gave at Iowa State Teachers College dealing with the subjectmatter of arithmetic and how to teach it. It was possible for students to enrol for credit, but the major portion of the audience consisted of teachers and parents not enrolled for credit. His report emphasizes the need for more research into the outcomes of such a course. Lehr (41) reported on her experience in giving a series of 15 27-minute TV lectures entitled "Invitation to Mathematics." She was quite enthusiastic about her experience and indicated the need for further experimentation of this type.

Special Programs

The Mathematical Association of America attempted to develop a special program thru its Committee on the Undergraduate Mathematical Program, commonly known as the Duren Committee (16). This committee concluded that the best service to the cause of liberal education would be accomplished by a *universal freshman course* for all reasonably qualified students with one year each of algebra and plane geometry, disregarding remedial courses. Its work was concerned with the organization of such a course. The committee's efforts were coordinated with those of the Committee on Mathematical Training of Social Scientists (9, 43) and the Committee on Engineering Mathematics (62). The report suggested a number of special problems on which the work of individuals and departments was solicited. The challenge was taken up in part by the Social Science Research Council and the University of Kansas which jointly supported a 1954 Kansas Summer Writing Group that produced *Universal Mathematics Part I* (60).

Duren (15) reported on the experience at Tulane University with *Universal Mathematics Part I*. It was used by 28 instructors with 750 students in engineering, liberal arts, and business administration. Students had considerable difficulty reading the book, which was thought unsuitable for students with scant background. It was pointed out that the material was not conceived as a proper textbook but "as a kind of mother of textbooks." Duren thought that the Tulane experience indicated that elementary calculus is more suited for freshman than are college algebra, trigonometry, and analytic geometry. The decision at Tulane was to continue with a modified form of the material rather than go back to a standard analysis text. *Universal Mathematics Part II* (61) is based in part upon the experiences at Tulane.

Layton (39) reported on a study of actual and proposed requirements in college programs for agricultural students, excluding agricultural engineering. He used the questionnaire method to obtain data from 75 colleges in 40 states. Entrance requirements for high-school students

were found to range from zero to three high-school units in mathematics. The mean college-mathematics requirement in Smith-Hughes programs was 3.91 semester hours and in other programs, 5.55 semester hours with college algebra the most frequently required course in both categories. The mean number of semester hours recommended by those responding to the questionnaire was 4.92 in Smith-Hughes programs and 5.43 in other programs. Agricultural mathematics was the most frequently recommended course in both categories. Another section of the questionnaire dealt with recommendations for topics for an agricultural mathematics course.

Geiselmann (21) reported on a current study dealing with mathematical deficiencies of students in the College of Agriculture at Cornell University. The preliminary part of the research was a comparison of the mathematical knowledge of seniors and freshmen using the *Cornell Mathematics Test*. Analysis of covariance technics was used, and individual differences in scholastic aptitude and academic achievement as measured by the *Ohio State University Psychological Test* and *Cooperative General Science Test* were removed. The seniors scored significantly better than the freshmen. Later phases of the study were to be concerned with an experimental remedial course.

Kemeny (32) described Dartmouth's new honors program which consisted of special calculus sections during the first two years and "honors major" work during the last two years. Kemeny noted that the number of mathematics majors at Dartmouth had increased significantly since the inception of the honors program and stated that the college output of PhD mathematicians might be increased tenfold by such a program. Corona (13) reported on a new program of concentration in mathematics worked out at Cardinal Stritch College in Milwaukee. The 40 semester hours required for concentration in mathematics included four hours of directed reading in the junior year and four hours of a coordinating seminar in the senior year designed to give the student an over-all picture of the various fields of mathematics. The author called for a comparative study involving students in such a program and those in a traditional major program.

The Education of Elementary-School Teachers

The mathematical training of elementary-school teachers at 85 institutions in 45 states was studied by Layton (40). He found that only 20 of the colleges required mathematics for entrance and the mean requirement of these 20 was 1.20 high-school units. Eleven others recommended a mean of 1.82 units. The mean mathematics content found for four-year curriculums for elementary-school teachers was 1.63 semester hours, and the mean requirement of methods in mathematics was .47 semester hours. This did not include courses which were part content and part method. The means of content courses in art, English, and geography were,

respectively, 4.28, 11.46, and 4.30 semester hours. Thirty-five schools required pure content courses in mathematics, 28 required courses which were part content and part method, and 26 required courses in the teaching of arithmetic. In a study of two-year curriculums for elementary-school teachers mathematics again held a very low position in requirements. None of 20 colleges offering a master's degree in elementary education, and for which data were available, specified any mathematics courses in content or method in the fifth-year program. Layton's findings are similar to those in his earlier study of state certification requirements cited in the last issue of this journal which was concerned with mathematics (33).

Snader (55) summarized data on the arithmetic programs offered at various state teachers colleges and on high-school mathematics required for admission to these institutions; he found that 76 percent required no mathematics for admission. He polled a representative group of specialists in arithmetic and reported their opinions on topics under consideration for a mathematics course for elementary-school teachers. The jurors thought that two years of high-school mathematics should be a prerequisite and that the college course should contain a minimum of six semester hours of both content and methods. They did not believe even this would be adequate for those preparing to teach in Grades VII and VIII.

Stipanowich (58) presented some results of a questionnaire survey of 70 mathematics-education specialists in 66 institutions in 32 states. Their opinions were solicited regarding the type of mathematics and the specific mathematical topics to be included in four-year elementary curriculums for students preparing to teach below Grade VII. Sixty-eight percent believed that there should be an entrance requirement of two years of high-school mathematics. Sixty-six percent favored requiring a certain level of proficiency in arithmetic as prerequisite to the required background courses in mathematics at the college level. Fifty-seven percent favored, for those preparing to teach in Grades VII and VIII, content different from that required of those preparing to teach below Grade VII; the median minimum program recommended for the latter group consisted of three semester hours and the median desirable program, six semester hours. Fifty-four percent favored presenting subjectmatter and methods in separate courses. Sixty of the 70 specialists suggested modifications of the programs in their own institutions, and the need for more subjectmatter training was most frequently mentioned.

Schaaf (52) summarized some of the research which showed that elementary-school teachers and prospective teachers had a very poor understanding of the fundamental principles of arithmetic. He cited various authorities on the need for 6 to 10 semester hours of appropriate college mathematics for prospective teachers of arithmetic and proceeded to outline such a course. The work of Orleans and Wandt (46), Weaver (64), and Phillips (47) illustrates the type of research summarized by

Schaaf. Orleans and Wandt (46) reported on a study of the understanding of arithmetic by teachers in the field and by those preparing to teach. A free-answer and a multiple-choice test were given to 1000 subjects in widely separated geographical locations. The tests covered the understanding and meaning of concepts of arithmetic. Few processes, concepts, or relationships in arithmetic could be found which were understood by a large percent of teachers. The authors believed that in too many cases a short cut had been learned as rote.

Weaver (64) was concerned with the apparent lack of background in arithmetic understanding on the part of undergraduates preparing to teach arithmetic in the elementary schools. He administered the *Glennon Test of Basic Mathematical Understandings* to four groups of students at the start of their course in "Methods of Teaching Arithmetic." His analysis of the data included use of the analysis of variance to demonstrate the permissibility of combining the separate group distributions into single composites for the test as a whole and for each of its five parts. The mean score on the entire test represented about 55 percent of the total items. There were correct responses on less than 50 percent of the items dealing with understanding of fractions and decimals and related processes and with the rationale of computation. There was less than 75 percent correct response to items on the decimal system of notation, understanding of integers, and related processes. Weaver attributed this poor showing to the lack of mathematics instruction appropriate to arithmetic understanding at all levels in the preparation of these students. He called for a required course in background mathematics relevant to arithmetic understandings for elementary-education majors prior to their methods course. In lieu of this he proposed the expedient of using part of the methods course for this background work. Using the *Glennon* test as both pretest and end-test with a group of 69 students, he found an improvement in understanding which was highly significant. The final level of understanding was about 70 percent (on the pretest the members of this group did not differ significantly from that one of the original four groups of which they were a part).

Phillips (47) studied the background and mathematical achievement of elementary-education majors in a course in arithmetic for teachers. On the *Schorling-Clark Hundred Problem Arithmetic Test* of mechanical mastery, the median of 268 students was 75 percent, but on a test of meaning and understanding of arithmetic the results were very poor. Information about the latter test was not given.

Hamilton (25) assessed, in the training program for arithmetic teachers, the effectiveness of material called "Make Believe Arithmetic" which is a set of number names and symbols organized on base six. The results were significantly in favor of the experimental method.

Attention was also given to the attitudes of prospective elementary-school teachers. Phillips (47) found that 17 to 34 percent of the students in the course in arithmetic for teachers remembered having a negative

or indifferent feeling toward mathematics when they were at various elementary-grade levels. This feeling seemed to have been attributable to their experiences with fractions, percent, and word problems. However, no quantitative evidence of the latter assertion was given. The students' liking of mathematics decreased even more in high school, and poor methods of presentation were given as the principal reason.

Dutton (18) made an extensive study of the measurement of attitudes toward arithmetic and constructed an arithmetic attitude scale using recognized technics for the measurement of attitudes. He used this scale in making an inventory (17) of the attitudes toward arithmetic held by prospective elementary-school teachers as they began methods courses in arithmetic. An attempt was made to identify factors responsible both for favorable and for unfavorable attitudes. Seventy-four percent of all responses were unfavorable, and the most frequently mentioned reasons centered around lack of understanding, poor teaching, and poor motivation. The influence of parental attitudes was recognizable in several of the responses. The data showed that many students came into methods classes with antagonistic attitudes toward arithmetic. The investigator concluded that the students had held highly emotional opinions which might have influenced their learning of methods considerably. The author believed that the frank class discussion of attitudes helped to overcome this adverse influence.

The Training of Secondary-School Teachers

The college training of prospective secondary-school teachers is profoundly influenced by state certification requirements which differ considerably from state to state. It is unfortunate that Dyer, Kalin, and Lord (19) in a widely quoted report of a survey stated that one-third of the states would license high-school mathematics teachers with no college mathematics at all and also included these states in the over-all average without pointing out that these states did not license any secondary-school teachers by subjectmatter field but merely checked that they had a college major. The responsibility for checking subject-matter competence in these states was that of the hiring official as pointed out in an editorial comment in the *Journal of Teacher Education* (57) which also included a listing of hours required in each state. Zant (69) reported on a study of the programs recommended by 17 colleges in Oklahoma in the revision of certification requirements for secondary-school mathematics teachers in that state. The state board of education required a minimum of 50 semester hours of general education, 21 of professional education, and 24 in specialization. Zant found a disappointing lack of originality and insight exhibited in the proposals for mathematical training made by the committees at the various colleges. Only four of the schools recommended a course in algebra beyond college algebra, and only two recommended mathematics of finance.

There was little consideration of giving the prospective teacher an idea of the general meaning of modern mathematics.

Steinbrenner (56) analyzed historical development and existing practices in teaching continuity, irrational numbers, and limits. His study was designed to clarify the meaning of these concepts for secondary-school teachers and to point out how they are a part of secondary-school mathematics. Rosenberg (51) studied the impact of modern mathematics on trigonometry. Certain concepts were selected from areas of higher mathematics, and technics were determined for discovering the implications of these concepts for teachers of trigonometry. One conclusion was an invalidation of the statement that college calculus courses have no value for teachers of trigonometry.

Lloyd (42) surveyed over 300 of the 1000 institutions of higher education which offer professional preparation for teaching mathematics. An examination of their catalogs revealed that only 75 offered more than one basic methods course for secondary-school teachers and one for elementary-school teachers. Questionnaires were sent to these 75 schools, and the 59 responses revealed among other things that laboratory methods were used to a very limited extent. About a dozen of the institutions were found to offer separate courses dealing primarily with the laboratory method; field work predominated in the majority of these courses.

Practice teaching has become a recognized part of the education of prospective teachers. Hardgrove (26) explored the use of professional experiences in conjunction with a methods course for mathematics teachers at Ohio State University. The students spent at least two hours a week as teacher-helpers in public-school mathematics classrooms. They gradually progressed from observation to having charge of the class for the entire period. It was believed that this experience combined with three hours of college classroom theory a week provided an effective course.

Wilson (66) described a course developed at San Francisco State College to improve the preparation of mathematics majors for teaching high-school courses in arithmetic and general mathematics; this course included both content and methods material. He called for a study of the value of such a course. Small's study (54) of teacher preferences for courses in a fifth-year program showed that teachers thought that such a course was valuable. Wilson (66) also called for other approaches to the problem. One such approach was suggested by Boyer (5) who proposed that separate programs be set up for training teachers for the two principal tracks in secondary-school mathematics. He was particularly concerned with providing competent and adequate instruction for basic (or general) mathematics courses. He indicated the need for further research in the area; his proposal has been viewed with considerable skepticism.

The shortage of mathematics teachers was documented by Maul (45) and led to special programs for preparing teachers. Maul (45) reported on a study based on the Eighth Annual National Teacher Supply and

Demand Report dealing with members of the 1954 and 1955 graduating classes who prepared to teach. From 1950 to 1955 there was a 40.8-percent decrease in the number of graduates prepared to teach in high school and a 51.3-percent decrease in the number prepared to teach mathematics. Of the members of the 1954 class prepared to teach mathematics only 59 percent actually did so in 1954-55. Maul gave a breakdown of the occupations of the others. Main and Wyckoff (44) reported on the experiment of a private preparatory school undertaking a pilot study in teacher education in science and mathematics. Persons with minimal or inadequate preparation taught at the private school part time under the supervision of experienced teachers while pursuing further study in the graduate schools of nearby colleges. Keller (31) reported on the development of a program at Purdue to prepare qualified retired military personnel to teach basic mathematics courses in college. A special sequence of courses covered two consecutive semesters and a summer session. The backbone of the proposed program was a series of courses in analysis.

At least one state required five years of college preparation for full certification. Moves in this direction were evident in several states. The general problem was summarized in a report of the Illinois Committee on the Strengthening of Mathematics Teaching (28). Small (54) investigated teacher preferences as to the type of work that should constitute a fifth year of education for teachers of secondary-school mathematics. He used a random sample of members of the National Council of Teachers of Mathematics stratified according to regional accrediting associations. Responses to questionnaire items were weighted, and internal checks of consistency were made. Twenty-seven statements with which teachers indicated significant agreement were selected and ranked. Courses called for included a course in methods of teaching arithmetic in the secondary schools; an advanced course in the teaching of secondary-school mathematics; a course in the history of mathematics; a course in basic number theory; a course in educational measurements; and courses in mathematical statistics, modern algebra, modern geometry, theory of equations, and mathematics of finance and the physical sciences. The teachers thought that about 50 percent of the work should be in mathematics courses and not more than 25 percent in professional education courses. A chi-square analysis showed that the opinions of teachers concerning any specific course were dependent on whether the teachers had taken the course. Those who had taken a course were more favorably inclined toward it with the one exception of modern algebra.

Need for Further Research

The need for additional study was mentioned in several of the papers cited above. Improved methods of research are also needed. Dodes (14) offered suggestions for improving research at all levels in mathematics

education. These suggestions emphasized the desirability of (a) at least temporary agreement on specific objectives, (b) coordination of research in practices which promise to accomplish the objectives, (c) insistence by directors of research that investigations take into account all related previous research, (d) research only by those who are already trained teachers and trained researchers, (e) the use of representative or stratified rather than simple random sampling, (f) the use of analysis of variance technics in order to calculate the interaction effect, and (g) the practice of new methods in a nonexperimental set-up for at least one semester before the experiment starts.

Dyer, Kalin, and Lord (19) reported on a survey carried out by the Educational Testing Service for the Carnegie Corporation in trying to describe the kinds of research activities which would lead to better mathematics teaching. Their booklet reported on some research in teacher education, much of which is mentioned elsewhere in this chapter, and called for much more research effort. They pointed out, in particular, the need for research into the role of personality factors in teaching mathematics, the relative effects of the teacher's background in subjectmatter —his training in instructional methods, his personal qualities, and his attitude toward his job—and into the importance of the teacher's influence as a factor in the mathematical success or failure of the students.

The need for further research on college mathematics curriculums and methods of teaching was stressed by Langer (38), Kline (37), and Hildebrandt (27). Hildebrandt discussed several aspects of the teaching of freshman and sophomore college-mathematics courses and pointed out the need for further research on student attitudes toward mathematics, success of experimental freshman programs with "modern" mathematical content, effectiveness of various methods of instruction, student use of library references in elementary mathematics, effectiveness of instructional aids, use of tests, and the preparation of teachers of mathematics. We share the concern that further research is needed in all these areas, without minimizing the significance of the papers cited herein.

Bibliography

1. ABERNETHY, JOHN R. "General Education Values of Mathematics and the Attempt of a Faculty To Teach Them." *Mathematics Teacher* 46: 241-45; April 1953.
2. AYRE, HENRY G. "Can a Single Course in Mathematics or the Sciences Fill the Dual Objectives of General Education and Training of Future Specialists?" *School Science and Mathematics* 53: 107-13; February 1953.
3. BEENKEN, MAY M., and OTHERS. "College Mathematics for Non-Science Students, Report of a Subcommittee of the California Committee for the Study of Education." *American Mathematical Monthly* 63: 639-42; November 1956.
4. BENTZ, RALPH P. "Critical Mathematical Requirements for the Program of the Community College." *Abstracts of Dissertations for the Year 1952.* Nashville, Tenn.: George Peabody College for Teachers, 1953. p. 13-20.
5. BOYER, LEE E. "A New Responsibility of Teacher Education Programs." *Mathematics Teacher* 47: 66-70; February 1954.

6. BROWN, KENNETH E. "Mathematics Education Research Studies." *Aids for Mathematics Education.* Washington, D. C.: U. S. Department of Health, Education, and Welfare, Office of Education. Circulars No. 377, 1953; No. 377-II, 1954; No. 377-III, 1955; No. 377-IV, 1956.
7. BROWN, KENNETH E., editor. "Research in Mathematics Education." *Mathematics Teacher* 46: 594-97; December 1953. 47: 51-52, January; 204-205, March 1954. 48: 21-25; January 1955.
8. BRUNE, IRVIN H. "Arithmetic via Television, II. A Course for Teachers and Parents." *Arithmetic Teacher* 3: 165-67; October 1956.
9. BUSH, ROBERT R., and OTHERS. "Mathematics for Social Scientists." *American Mathematical Monthly* 61: 550-61; October 1954.
10. CAMERON, E. A. "Some Observations on Undergraduate Mathematics in American Colleges and Universities." *American Mathematical Monthly* 60: 151-55; March 1953.
11. CHILDS, GAYLE B. "Success in Initial University Mathematics Courses of Students with Correspondence and Non-Correspondence Backgrounds in High School Mathematics." *Journal of Educational Research* 49: 607-12; April 1956.
12. COGAN, EDWARD J. "Survey Courses in Mathematics for the Liberal Arts Student." *American Mathematical Monthly* 62: 319-22; May 1955.
13. CORONA, SISTER MARY. "Seminars—An Integrating Force in a Program of Concentration." *Mathematics Teacher* 48: 209-13; April 1955.
14. DODES, IRVING A. "The Science of Teaching Mathematics." *Mathematics Teacher* 46: 157-66; March 1953.
15. DUREN, WILLIAM L., JR. "Tulane Experience with *Universal Mathematics Part I.*" *American Mathematical Monthly* 63: 199-202; March 1956.
16. DUREN, WILLIAM L., JR., and OTHERS. "Report of the Committee on the Undergraduate Mathematical Program." *American Mathematical Monthly* 62: 385-92; May 1955.
17. DUTTON, WILBUR H. "Attitudes of Prospective Teachers Toward Arithmetic." *Elementary School Journal* 52: 84-90; October 1951.
18. DUTTON, WILBUR H. "Measuring Attitudes Toward Arithmetic." *Elementary School Journal* 55: 24-31; September 1954.
19. DYER, HENRY S.; KALIN, ROBERT; and LORD, FREDERIC M. *Problems in Mathematical Education.* Princeton: Educational Testing Service, 1956. 50 p.
20. FILANO, ALBERT E. "The Ability of College Freshmen To Read Mathematics Texts Independently with Understanding." *School Science and Mathematics* 57: 16-18; January 1957.
21. GEISELMANN, HARRISON. "Mathematical Deficiencies of College Freshmen." *Mathematics Teacher* 49: 22-25; January 1956.
22. GREEN, JOHN W. "Report of the Survey." *Report on a Conference on Undergraduate Mathematics Curricula.* New Haven: Yale University, 1957. p. 45-48.
23. HABEL, ELMER A. "Does the Arithmetic in Algebra Textbooks Prepare for Trigonometry?" *School Science and Mathematics* 51: 488-91; June 1951.
24. HAGGARD, J. D. *College Mathematics for the General Student.* Doctor's thesis. Columbia: University of Missouri, 1951. 193 p. Abstract: *Dissertation Abstracts* 11: 570-72; No. 3, 1951.
25. HAMILTON, ELBERT W. *The Notational System as an Aid to Understanding Arithmetic.* Doctor's thesis. Iowa City: State University of Iowa, 1956. 193 p. Abstract: *Dissertation Abstracts* 16: 1849-50; No. 10, 1956.
26. HARDGROVE, CLARENCE E. "The Use of Professional Laboratory Experiences in a Methods Course." *Emerging Practices in Mathematics Education.* Twenty-Second Yearbook. Washington, D. C.: National Council of Teachers of Mathematics, a department of the National Education Association, 1954. p. 188-97.
27. HILDEBRANDT, EMANUEL H. C. "For a Better Mathematics Program in the College." *Mathematics Teacher* 49: 89-99; February 1956.
28. HOHN, FRANZ E., and OTHERS. "Report to the Illinois Section of the Mathematical Association of America of Its Committee on the Strengthening of Mathematics Teaching." *American Mathematical Monthly* 60: 652-61; November 1953.
29. HUNTER, LOUISE S. *Pre-Freshman Mathematics in State Colleges and Universities.* Doctor's thesis. Charlottesville: University of Virginia, 1953. 264 p. Abstract: *Dissertation Abstracts* 14: 1051-52; No. 7, 1954.
30. JONES, PHILLIP S. *Understanding Numbers: Their History and Use.* Ann Arbor, Mich.: Ulrich's Bookstore, 1954. 50 p.

31. KELLER, MARION W. "A Training Program To Prepare Qualified Retired Military Personnel To Teach Basic Mathematics Courses in College." *Educational Record* 37: 233-34; July 1956.
32. KEMENY, JOHN G. "Honors Mathematics at Dartmouth." *Mathematics Teacher* 49: 455-57; October 1956.
33. KINNEY, LUCIEN B; EAGLE, EDWIN; and PURDY, CHARLES. "The Teaching of Mathematics in High School and College." *Review of Educational Research* 21: 305-16; October 1951.
34. KINSELLA, JOHN J., editor. "Research in Mathematics Education." *Mathematics Teacher* 44: 250-52; April 1951. 45: 273-75; April 1952. 46: 52-54, January; 218-19, March; 346-47, May 1953.
35. KINZER, JOHN R., and KINZER, LYDIA G. "Non-Credit Algebra as Preparation for Later Mathematics Courses." *Educational Research Bulletin* 32: 57-59; March 11, 1953.
36. KLINE, MORRIS. "Freshman Mathematics as an Integral Part of Western Culture." *American Mathematical Monthly* 61: 295-306; May 1954.
37. KLINE, MORRIS. "Mathematics Texts and Teachers: A Tirade." *Mathematics Teacher* 49: 162-72; March 1956.
38. LANGER, RUDOLPH E. "The Things I Should Have Done, I Did Not Do." *American Mathematical Monthly* 59: 443-48; August-September 1952.
39. LAYTON, WILLIAM I. "College Mathematical Training for Students Specializing in Agriculture." *Mathematics Teacher* 50: 55-57; January 1957.
40. LAYTON, WILLIAM I. "Mathematical Training Prescribed by Teachers Colleges in the Preparation of Elementary Teachers." *Mathematics Teacher* 46: 551-56; December 1951.
41. LEHR, MARGUERITE. "An Experiment with Television." *American Mathematical Monthly* 62: 15-21; January 1955.
42. LLOYD, DANIEL B. "The Laboratory Method in Mathematics Education." *Emerging Practices in Mathematics Education.* Twenty-Second Yearbook. Washington, D. C.: National Council of Teachers of Mathematics, a department of the National Education Association, 1954. p. 210-22.
43. MADOW, WILLIAM G., and OTHERS. "Recommended Policies for the Mathematical Training of Social Scientists: Statement by a Committee of the Council." *Items* 9: 13-16; June 1955. (A publication of the Social Science Research Council.)
44. MAIN, CHARLOTTE, and WYCKOFF, LILLIAN. "A Plan for Training Teachers." *School Science and Mathematics* 57: 18-19; January 1957.
45. MAUL, RAY C. "Where Do Eligible Mathematics Teachers Go?" *Mathematics Teacher* 48: 397-400; October 1955.
46. ORLEANS, JACOB S., and WANDT, EDWIN. "The Understanding of Arithmetic Possessed by Teachers." *Elementary School Journal* 53: 501-507; May 1953.
47. PHILLIPS, CLARENCE. "Background and Mathematical Achievement of Elementary Education Students in Arithmetic for Teachers." *School Science and Mathematics* 53: 48-52; January 1953.
48. RASMUSSEN, OTHO M. "Mathematics Used in Courses in Various Departments in a University." *Mathematics Teacher* 48: 237-42; April 1955.
49. READ, CECIL B., and KLEIN, ANN E. "An Analysis of Mathematics Courses in Four Year Colleges." *School Science and Mathematics* 55: 40-55; January 1955.
50. ROGERS, HARTLEY, JR. "A General Education Course in Pure Mathematics." *American Mathematical Monthly* 63: 460-65; August-September 1956.
51. ROSENBERG, HERMAN. *The Impact of Modern Mathematics on Trigonometry: A Study of the Significance of Certain Concepts of Higher Mathematics for the Teacher of Trigonometry.* Doctor's thesis. New York: New York University, 1955. 318 p. Abstract: *Dissertation Abstracts* 15: 1796-97; No. 10, 1955.
52. SCHAAF, WILLIAM L. "Arithmetic for Arithmetic Teachers." *School Science and Mathematics* 53: 537-43; October 1953.
53. SEIGLE, WILLIAM F. "Prediction of Success in College Mathematics at Washburn University." *Journal of Educational Research* 47: 577-88; April 1954.
54. SMALL, DWAIN E. "The Fifth Year of Teacher Education for Teachers of Mathematics." *Mathematics Teacher* 50: 199-203; March 1957.
55. SNADER, DANIEL W. "Mathematical Background for Teachers of Arithmetic." *Arithmetic Teacher* 3: 59-65; March 1956.

56. STEINBRENNER, ARTHUR H. *A Study of the Concept of Continuity for Teachers of Secondary School Mathematics.* Doctor's thesis. New York: Teachers College, Columbia University, 1955. 173 p. Abstract: *Dissertation Abstracts* 15: 2137-38; No. 11, 1955.
57. STINNETT, T. M. "Math and Science Again." (Editorial) *Journal of Teacher Education* 7: 194, 267-73; September 1956.
58. STIPANOWICH, JOSEPH J. *The Development and Appraisal of a Course in Basic Mathematics for Prospective Elementary School Teachers.* Doctor's thesis. Evanston, Ill.: Northwestern University, 1956. 459 p.
59. SUBCOMMITTEE ON UNDERGRADUATE COLLEGES OF THE SURVEY OF RESEARCH POTENTIAL AND TRAINING IN THE MATHEMATICAL SCIENCES. *Report on a Conference on Undergraduate Mathematics Curricula.* New Haven: Yale University, 1957. 71 p.
60. SUMMER (1954) WRITING GROUP OF THE DEPARTMENT OF MATHEMATICS, UNIVERSITY OF KANSAS. *Universal Mathematics Part I, Functions and Limits.* Lawrence: University of Kansas Student Union Bookstore, 1954. 310 p.
61. SUMMER (1954) WRITING GROUP OF THE DEPARTMENT OF MATHEMATICS, UNIVERSITY OF KANSAS. *Universal Mathematics Part II, Structures in Sets.* New Orleans: Tulane University Bookstore, 1955. (Pages not numbered consecutively.)
62. THOMAS, GEORGE B., and OTHERS. "Report of the Joint Committee of the American Society for Engineering Education and the Mathematical Association of America on Engineering Mathematics." *American Mathematical Monthly* 62: 385-92; May 1955.
63. WAHLERT, HOWARD E. *Elementary Mathematics in Arts Colleges.* Doctor's thesis. New York: Teachers College, Columbia University, 1952. 154 p. Abstract: *Dissertation Abstracts* 12: 530; No. 4, 1952.
64. WEAVER, J. FRED. "A Crucial Problem in the Preparation of Elementary-School Teachers." *Elementary School Journal* 56: 255-61; February 1956.
65. WILLIAMS, WYMAN L. "What the Colleges Are Doing about the Poorly Prepared Student." *American Mathematical Monthly* 61: 86-88; February 1954.
66. WILSON, JACK D. "Arithmetic for Majors?" *Mathematics Teacher* 46: 560-64; December 1953.
67. WOLFE, JACK M. "Proximity of Prerequisite Learning and Success in Trigonometry in College." *Mathematics Teacher* 49: 605-606; December 1956.
68. WOODBY, LAUREN G. "The Content of a Junior College Course in Mathematics for the Purpose of General Education." *School Science and Mathematics* 53: 717-26; December 1953.
69. ZANT, JAMES H. "The Revision of Certification Requirements for Secondary Mathematics Teachers in Oklahoma." *Mathematics Teacher* 47: 467-75; November 1954.

CHAPTER VII

Studies on Motivation and Identification of Gifted Pupils

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A CHAPTER on this topic has not previously been included in the science number of the REVIEW. Because of the quantity of material to be covered, it seemed expedient to limit the period considered to the time since the review by T. Ernest Newland (40) in this journal in December 1953. Readers who wish to become acquainted with earlier publications may refer to this Newland summary.

The Manpower Emphasis

During recent years there has been a tremendous increase in the amount of attention focused on gifted children. Probably the most important reason for this increase is our national concern about possible shortages of top-level personnel, particularly in the science fields. Wolfbein (60) surveyed occupational trends and showed that the high-level occupations will need increasing proportions of the total labor force by 1965 and 1975. Wolfle (61), in a detailed and definitive survey of our potential resources of specialized talent, found that only approximately half of the students who are intellectually in the top 5 percent of the population now graduate from college and thus qualify themselves for high-level intellectual work. He analyzed the reasons for the loss and made some recommendations for improvement of the situation.

Not all educators were comfortable with this emphasis on the development of talents of gifted persons primarily for the sake of the national welfare. Faust (22) called attention to the importance of our responsibility to the individual in a democratic society and recommended that educational programs be designed to develop superior individuals rather than simply to channel brainpower into work important to the nation. Anderson (1) and Getzels (25) also registered concern over the tendencies some writers showed to equate *manpower* with *man*.

The Encouragement of College Going

The evidence that accumulated with regard to the need for and wastage of high-level talent led to attempts to discover why such a large proportion of highly intelligent youth did not go to college. Berdie (5) conducted a questionnaire study of all 1950 high-school seniors in Minnesota, supplemented by various interview studies. His figures showed that sex and geography affected college going. A smaller proportion of girls than of

boys and a smaller proportion of rural than of urban youth planned to obtain higher education. Money was mentioned as a reason by about one-third of those not going to college; cultural factors seemed to be somewhat more important than economic factors.

The Educational Testing Service (21) conducted a very extensive survey of the plans of 32,750 seniors in 478 high schools, almost 7000 of whom were followed up to ascertain whether or not they had actually entered college. The higher the ability level, the larger was the proportion who planned to enter college and who actually went. Other factors bearing on the decision that seemed to operate at all ability levels were friends, class standing, opportunity for counseling, having taken science and mathematics in high school, number of siblings, father's occupation, father's education, and the availability of funds. Cole (13), who carried out a similar survey with a 5-percent sample of all high schools in the United States, discovered similar factors. Havighurst (29) discussed conditions favorable and unfavorable to the development of talent with special emphasis on social class and sex differences.

The realization that a part but not all of the problem of enabling gifted students to go to college was financial led to more intelligent planning for the awarding of scholarships. West (54) summarized the research on motivation that should be taken into consideration when policies with regard to scholarships are being formulated. Stalnaker (46) gave an account of the National Merit Scholarship Program, organized as a nonprofit corporation in 1955 for the purpose of selecting able students and awarding scholarships on the basis of need. During the first year of the program 556 four-year scholarships were awarded. Parker and Wright (42) reported some evidence from Brigham Young University that obtaining a scholarship made the difference between going and not going to college in only a small percent of the cases (7 to 18).

Broader Concepts of Giftedness

While the intelligence test was still the predominant means of selecting gifted children and formed the basis for such proposals as that of Morgan (38) that the bright children be selected for special attention as soon as they enter school, there was increasing interest among research workers in other methods for the identification of talented individuals. Greenberg (26) recommended that a search be made for genuinely creative individuals. In three large-scale community projects an effort was made to do this.

In Quincy, Illinois, Bowman and others (10, 11) outlined a 10-year project for using community resources to help both talented and disturbed children, and DeHaan (18) summarized the testing and observational methods that had been worked out for the identification of the gifted. A report issued by the Portland, Oregon, Public Schools (45) described the methods the research staff developed for identifying talent in seven

areas: art, music, mechanical comprehension, creative writing, creative dance, creative drama, and social leadership. The Portland project, in which the public school system and Reed College worked together, had many facets, including enrichment of the educational program at all levels, research on motivation and differential achievement among the gifted, and inservice development of teachers.

Another large-scale research undertaking, begun in 1954, was the Talented Youth Project of the Horace Mann-Lincoln Institute of School Experimentation at Columbia in New York. Passow (43) and Passow and others (44) outlined its aims and procedures. The Institute worked closely with the cooperating school systems in developing the research plans.

Less immediately practical in its aims but of great potential importance in our understanding of high-level mental ability was the work of Guilford (27) on the structure of intellect. Based on factor analyses of reasoning, creativity, planning, evaluation, and other aspects of high-level thinking, Guilford formulated a theory in which intellect is subdivided first into memory and thinking. Thinking breaks down into three main divisions: cognition, production, and evaluation. Within each of these categories abilities can be arranged in a two-dimensional classification, by *classes of information* and by *form* in which the information occurs. It is possible that this theory of intellect, based on actual correlations between test scores, will eventually have a profound effect on our methods for identifying different *kinds* of intellectually gifted children.

Temperament, Motivation, and School Achievement

The nonintellectual components of talent and achievement continued to interest research workers. Bonsall and Stefflre (9) gave the *Guilford-Zimmerman Temperament Survey* to 1359 high-school boys, along with the *Primary Mental Abilities Tests*. As previous studies have indicated, boys scoring high on the mental abilities also obtained superior scores on the temperament survey. The superiority reported in the variables, "Restraint" and "Thoughtfulness," however, seemed to be related more to family background than to intelligence itself. Horrall (31) found that the low achievers differed from high achievers from a gifted college-freshman group in a number of respects. They showed evidence of more conflict with family and close friends; more concern with health, conduct, and sex; less optimism; more feelings of inferiority; and poorer contact with reality. These differences suggested that in the low achievers ego control did not develop in an optimal manner.

At the grade-school level, Dye (20) found that a gifted group did not differ greatly from an average group in attitudes toward school, but that there was a somewhat higher proportion of dissatisfied and unhappy children among the gifted. Walsh (53), using a story-completion test involving doll play, found that high-achieving gifted boys differed from

the low-achieving in that they showed more freedom to pursue interests and express emotions, more acceptance as members of their families, and more adequate, constructive, resourceful activity. These findings also suggested differences in socialization and ego development.

Educational Programs—Enrichment

Many communities and schools thruout the country tried out experimental plans for meeting the needs of the gifted. Hall (28) gave a readable account of the Cleveland system of special classes in the grade schools and high schools. Barbe (2, 3, 4) reported on a follow-up study of the graduates of these classes from 1938 to 1952. Generally good adjustment was indicated, and a large majority of the graduates approved of the program. Dunlap (19) presented evidence from a small group that an enrichment program in grade school had increased the proportion of honor grades in junior high school. Wrightstone (63) described and explained the advantages of the special career high schools in New York City.

Educational Programs—Acceleration

Evidence continued to pile up that the effects of acceleration on gifted students are favorable rather than the reverse. Flesher and Pressey (23) presented a follow-up study, 10 years after graduation, of a group of college women who completed a four-year program in three years. In all respects their adjustment had been at least as good as that of the controls. More of them obtained advanced degrees and continued their careers after marriage. Pressey was one of the foremost spokesmen for acceleration as a method of meeting the needs of the gifted, and this study added to the impressive body of evidence he had previously assembled.

Various writers recommended acceleration at different educational levels and by various means. Worcester (62) advocated allowing early entrance to elementary school and time saving of some sort at the high-school and early college stage. Birch (6) presented follow-up information on a group of 43 children who had been admitted to first grade a few months younger than the minimum age of 5 years, 7 months. The reports on these children from one to three years later were overwhelmingly favorable.

Justman (33, 34) compared students from special junior high-school classes that finished in two years with nonaccelerated control students of the same level of ability. There were no significant differences on the personality inventory and sociometric ratings, and academic achievement tests showed the accelerated group to be clearly superior in subjectmatter knowledge.

Several ways of saving time at the high-school and college level were explored. Kemper (36) outlined four acceleration plans ranging from grade school to graduate school and stressed the need for integration of

secondary school and college. The Fund for the Advancement of Education (24) reported on four projects for the benefit of the gifted, three of them designed to accelerate the progress of bright students thru secondary school and college. One of these, under which college credit was given for specially designed courses taken in secondary school, was taken over as a permanent project by the College Entrance Examination Board (14). Cornog (15) explained what the secondary schools participating in the program must do.

Jones and Ortner (32) reported on a system of giving college credit by examination that had been in operation at the University of Buffalo for more than 20 years. A follow-up study of a group of students obtaining nine or more credits in this manner indicated that their record was somewhat superior to that of a matched control group. Their drop-out rate was lower, and more of them went on to graduate schools.

Among educators there apparently was still a considerable amount of opposition to acceleration. Wilson (55), in a questionnaire study, found that 50 percent of the public-school educators and 20 percent of the college and university faculty members he polled were against acceleration. The reason most commonly given was concern for the personalities of gifted children. Justman and Wrightstone (35), from a questionnaire addressed to teachers in four New York high schools, found 65 percent of the respondents favorable to special progress classes and 29 percent unfavorable. Attitudes were less favorable among older teachers and among those who had not had experience in teaching the special classes. It appeared that some of the misgivings teachers felt about the effects of acceleration on personality and social adjustment persisted in spite of a considerable body of evidence that it does not in fact have unfavorable effects.

Guidance of the Gifted

Many writers on the general problem stressed the importance of guidance in promoting optimal utilization of talents. Stedman (47) carried on a questionnaire survey of 20 Western colleges and universities to ascertain whether any special guidance was being given to the more able students. Results showed that while means of identification and facilities for counseling were available, little special treatment or help to the gifted as a group was given by student personnel departments. Witty (56) outlined some specific things that guidance workers and counselors could do to help the gifted.

Science Talent and Its Development

Because of the continuing emphasis on our actual or potential shortage of scientists, much attention was given to this special area. Bloom (7, 8) and Witty and Bloom (58, 59) summarized what outstanding schools

were doing to identify talented science students and give them a stimulating kind of science teaching.

Terman (48, 49, 50) analyzed the differences in childhood characteristics between members of his gifted group who went into science and those who entered other fields. The detailed statistical comparisons indicated that the most striking difference was in *sociability* as measured in a variety of ways. Scientists were less interested in many kinds of social relations from childhood on.

Brandwein (12) outlined his theory of science ability. He postulated three factors: (a) a genetic factor producing high verbal and mathematical ability; (b) a predisposing factor, motivational in nature, consisting of persistence and what he called "questing"; and (c) an activating factor—opportunities and a special kind of teaching. He described the outstanding science program at the Forest Hills High School. It appeared that where there is such a program for career students in science, and it is clearly explained to them, persons with science talent *identify themselves.*

General Discussions and Surveys

The period produced a considerable number of summaries, published conference reports, symposiums, and the like, only a few of which can be singled out for special mention. Miles (37) brought her comprehensive chapter up to date. It constituted one of the best available summaries of more than three decades of research. Terman (49) commented on his long career of research in this area and stressed the conclusions that seemed to him to be most significant: the importance of early identification, the generally favorable effects of acceleration, and the importance of nonintellectual factors in addition to high IQ. Terman and Oden (51) in another paper emphasized some of the same points.

Havighurst, Stivers, and DeHaan (30) made a comprehensive survey of outstanding school and community programs. Traxler (52) edited a report of a conference sponsored in 1955 by the Educational Records Bureau and the American Council on Education. A symposium entitled "Curriculum and the Gifted" (17) included a discussion of all the major issues, reported on outstanding programs of various kinds, and summarized important recent publications. Witty (57) also presented information about outstanding programs.

Cutts and Moseley (16) wrote a new text designed to give practical help to classroom teachers. It covered identification, enrichment, acceleration, motivation, and guidance.

Finally, some definite ideas as to the sort of research that should be done took shape. Newland (39), after specifying that he was using the word *gifted* to mean the top tenth of the population, outlined three research problems: (a) socio-emotional needs of the gifted; (b) the nature of giftedness and its relation to creativeness, special conceptual processes, and the like; and (c) the effects of education. O'Shea (41) gave

the report of a subcommittee of the American Psychological Association, consisting of a large number of specific research questions having to do with the needs of gifted children and the effects of various educational procedures. It would seem that the time is ripe for some definitive research on these problems.

Bibliography

1. ANDERSON, HAROLD E. "Educational News and Editorial Comment." *School Review* 64: 385-90; December 1956.
2. BARBE, WALTER B. "Evaluation of Special Classes for Gifted Children." *Exceptional Children* 22: 60-62; November 1955.
3. BARBE, WALTER B. "Interests and Adjustments of Adults Who Were Identified in Childhood as Gifted." *Progressive Education* 32: 145-50; September 1955.
4. BARBE, WALTER B. "Occupational Adjustments of the Mentally Gifted." *Vocational Guidance Quarterly* 5: 74-76; Winter 1956-57.
5. BERDIE, RALPH F. *After High School—What?* Minneapolis: University of Minnesota Press, 1954. 240 p.
6. BIRCH, JACK W. "Early School Admission for Mentally Advanced Children." *Exceptional Children* 21: 84-87; December 1954.
7. BLOOM, SAMUEL W. "Early Identification of Potential Scientists." *School Science and Mathematics* 55: 287-95; April 1955.
8. BLOOM, SAMUEL W. "Science Provisions for the Rapid Learner—A Symposium." *Science Teacher* 20: 161-63, 182-84, September; 243-46, October; 291-97, November 1953.
9. BONSALL, MARCELLA R., and STEFFLRE, BUFORD. "The Temperament of Gifted Children." *California Journal of Educational Research* 6: 162-65; September 1955.
10. BOWMAN, PAUL H., and OTHERS. *Mobilizing Community Resources for Youth.* Supplementary Educational Monographs, No. 85. Chicago: University of Chicago Press, 1956. 138 p.
11. BOWMAN, PAUL H., and OTHERS. *Studying Children and Training Counselors in a Community Program.* Supplementary Educational Monographs, No. 78. Chicago: University of Chicago Press, 1953. 136 p.
12. BRANDWEIN, PAUL F. *The Gifted Student as Future Scientist.* New York: Harcourt, Brace and Co., 1955. 107 p.
13. COLE, CHARLES C., JR. *Encouraging Scientific Talent.* New York: College Entrance Examination Board, 1956. 259 p.
14. COLLEGE ENTRANCE EXAMINATION BOARD. *Advanced Placement Program.* New York: the Board, 1956. 136 p.
15. CORNOG, WILLIAM H. "Initiating an Educational Program for the Able Students in the Secondary School." *School Review* 65: 49-59; March 1957.
16. CUTTS, NORMA E., and MOSELEY, NICHOLAS. *Teaching the Bright and Gifted.* Englewood Cliffs, N. J.: Prentice-Hall, 1957. 268 p.
17. DEHAAN, ROBERT F. "Curriculum and the Gifted." *Educational Leadership* 13: 206-67; March 1957.
18. DEHAAN, ROBERT F. "Identifying Gifted Children." *School Review* 65: 41-48; Spring 1957.
19. DUNLAP, JAMES M. "Gifted Children in an Enriched Program." *Exceptional Children* 21: 135-37; January 1955.
20. DYE, MYRTLE G. "Attitudes of Gifted Children Toward School." *Educational Administration and Supervision* 42: 301-308; May 1956.
21. EDUCATIONAL TESTING SERVICE. "Factors Affecting Attendance at College Are Same Factors Affecting College Plans." *ETS Developments* 5: 1; March 1957.
22. FAUST, CLARENCE H. "Why the New Concern for Educating the Gifted." *School Review* 65: 12-19; March 1957.
23. FLESHER, MARIE A., and PRESSEY, SIDNEY L. "War-Time Accelerates Ten Years After." *Journal of Educational Psychology* 46: 228-38; April 1955.
24. FUND FOR THE ADVANCEMENT OF EDUCATION. *Bridging the Gap Between School and College.* New York: the Fund, 1953. 127 p.

25. GETZELS, JACOB W. "Social Values and Individual Motives: The Dilemma of the Gifted." *School Review* 65: 60-63; March 1957.
26. GREENBERG, LEAH. "Critique of Classic Methods of Identifying Gifted Children." *School Review* 63: 25-30; January 1955.
27. GUILFORD, JOY P. "The Structure of Intellect." *Psychological Bulletin* 53: 267-93; July 1956.
28. HALL, THEODORE. *Gifted Children: The Cleveland Story.* Cleveland, Ohio: World Publishing Co., 1956. 90 p.
29. HAVIGHURST, ROBERT J. "Conditions Favorable and Detrimental to the Development of Talent." *School Review* 65: 20-26; March 1957.
30. HAVIGHURST, ROBERT J.; STIVERS, EUGENE; and DEHAAN, ROBERT F. *A Survey of the Education of Gifted Children.* Supplementary Educational Monographs, No. 83. Chicago: University of Chicago Press, 1955. 114 p.
31. HORRALL, BERNICE M. "Academic Performance and Personality Adjustments of Highly Intelligent College Students." *Genetic Psychology Monographs* 55: 3-83; February 1957.
32. JONES, EDWARD S., and ORTNER, GLORIA K. *College Credit by Examination.* Studies, Vol. 21, No. 3. Buffalo: University of Buffalo, January 1954. p. 128-201.
33. JUSTMAN, JOSEPH. "Academic Achievement of Intelligently Gifted Accelerants and Non-Accelerants in Junior High School." *School Review* 62: 142-50; March 1954.
34. JUSTMAN, JOSEPH. "Personal and Social Adjustment of Intellectually Gifted Accelerants and Non-Accelerants in Junior High Schools." *School Review* 61: 468-78; November 1953.
35. JUSTMAN, JOSEPH, and WRIGHTSTONE, J. WAYNE. "The Expressed Attitudes of Teachers Toward Special Classes for Intellectually Gifted Children." *Educational Administration and Supervision* 42: 41-48; March 1956.
36. KEMPER, JOHN M. "Saving Time in the Transition from Secondary School to College." *Educational Record* 37: 310-11; October 1956.
37. MILES, CATHERINE C. "Gifted Children." *Manual of Child Psychology.* Second edition. (Edited by Leonard Carmichael.) New York: John Wiley and Sons, 1954. p. 984-1063.
38. MORGAN, ANTONIA B. "Identification and Guidance of Gifted Children." *Scientific Monthly* 80: 171-74; March 1955.
39. NEWLAND, T. ERNEST. "Essential Research Directions on the Gifted." *Exceptional Child* 21: 291-96; May 1955.
40. NEWLAND, T. ERNEST. "The Gifted." *Review of Educational Research* 23: 417-31; December 1953.
41. O'SHEA, HARRIET E., chairman. "Needed Research on Gifted Children." *American Psychologist* 9: 77-78; February 1954.
42. PARKER, CLYDE A., and WRIGHT, E. WAYNE. "Do Scholarships Influence College Attendance?" *Journal of Higher Education* 27: 147-50; March 1956.
43. PASSOW, AARON H. "Planning for Talented Youth: A Research Project." *Educational Leadership* 13: 249-51; January 1956.
44. PASSOW, AARON H., and OTHERS. *Planning for Talented Youth.* New York: Teachers College, Columbia University, 1955. 84 p.
45. PORTLAND PUBLIC SCHOOLS. *Progress Report No. II of the Cooperation Program for Students with Exceptional Endowment.* Portland, Oreg.: Board of Education, April 1954. 53 p. (Mimeo.)
46. STALNAKER, JOHN M. "National Program for Discovering Students of Exceptional Ability." *Exceptional Children* 23: 234-37; March 1957.
47. STEDMAN, EDITH. *The Gifted Student and Student Personnel Programs in Colleges and Universities.* Pasadena, Calif.: Western Personnel Institute, 1956. 47 p.
48. TERMAN, LEWIS M. "Are Scientists Different?" *Scientific American* 192: 25-29; January 1955.
49. TERMAN, LEWIS M. "The Discovery and Encouragement of Exceptional Talent." *American Psychologist* 9: 221-30; June 1954.
50. TERMAN, LEWIS M. *Scientists and Nonscientists in a Group of 800 Gifted Men.* Psychological Monographs, No. 378. Washington, D. C.: American Psychological Association, 1954. 44 p.

51. TERMAN, LEWIS M., and ODEN, MELITA H. "Major Issues in the Education of Gifted Children." *Journal of Teacher Education* 5: 230-32; September 1954.
52. TRAXLER, ARTHUR E., editor. *Selection and Guidance of Gifted Students for National Survival.* Washington, D. C.: American Council on Education, 1956. 164 p.
53. WALSH, ANN M. *Self-Concepts of Bright Boys with Learning Difficulties.* New York: Teachers College, Columbia University, 1956. 79 p.
54. WEST, ELMER D. *Background for a National Scholarship Policy.* Washington, D. C.: American Council on Education, 1956. 160 p.
55. WILSON, FRANK T. "Educators' Opinions about Acceleration of Gifted Students." *School and Society* 80: 120-22; October 16, 1954.
56. WITTY, PAUL A. "Guidance of the Gifted." *Personnel and Guidance Journal* 33: 136-39; November 1954.
57. WITTY, PAUL A. "Programs and Procedures for the Education of Gifted Children." *Journal of Teacher Education* 5: 225-29; September 1954.
58. WITTY, PAUL A., and BLOOM, SAMUEL W. "Conserving Ability in the Sciences." *Exceptional Children* 22: 10-16; October 1955.
59. WITTY, PAUL A., and BLOOM, SAMUEL W. "Science Provisions for the Gifted." *Exceptional Children* 20: 244-50; March 1954.
60. WOLFBEIN, SEYMOUR L. "The Creative Manpower Shortage in the United States." *School Review* 65: 27-34; March 1957.
61. WOLFLE, DAEL. *America's Resources of Specialized Talent—A Current Appraisal and a Look Ahead.* New York: Harper and Brothers, 1954. 332 p.
62. WORCESTER, DEAN A. *The Education of Children of Above-Average Mentality.* Lincoln: University of Nebraska Press, 1956. 58 p.
63. WRIGHTSTONE, J. WAYNE. "The Career High School." *Educational Leadership* 13: 236-40; January 1956.

CHAPTER VIII

Implications of Research in the Psychology of Learning for Science and Mathematics Teaching

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RESEARCH in the psychology of learning may be likened to basic research in the physical sciences. The facts discovered by basic research in science are the foundation for new applications of science in industry, education, and government. Similarly, research in learning may be the basis for the development of new technics, new materials, and new evaluation instruments in the classroom.

An attempt has been made in this chapter to select those studies of learning that appear to have a direct bearing on mathematics and science education. It was the original intent of the writer to survey only those studies of learning during the past six years considered to be significant in their design and execution. However, very few studies that satisfy statistical requirements such as randomness, replication, and the use of controls were found, nor were there many studies of important permanent learning. The paucity of research on learning is illustrated by the absence of studies on problem solving. For example, no study on general problem solving was found comparable to the study by Buswell and Kersh (18) on patterns of thinking in solving arithmetical problems.

Theories of Learning

In view of the current theories of learning regarding concept formation, it seems essential that there be many research studies to test the validity of these theories of learning as they apply to specific areas of education such as science and mathematics. Since many of the experiments of the 1920's and early 1930's were based on different theories of learning—for example, on the stimulus-response theory of Thorndike—it would seem important that many of these studies be repeated in the light of currently accepted learning theories. However, very few studies which tested organismic psychological learning theories were available. No study which attempted to test directly the validity of current learning theories similar to the studies by Swenson, Anderson, and Staley (72) was reported in the past six years.

Theories of learning have been discussed at length with varying agreement as to their relative merits. A critical evaluation of them was made by Adams (2), Brown and others (15), English (31), Estes and others (32), and Restle (66). Dissertation studies of conditioning were completed by Daily (24) and Dawson (25). Denny and Adelman (27)

developed a new interpretation of learning which they termed "elicitation theory." This theory emphasized the importance of reward objects or of goal objects in instrumental learning. These experiments tested the theory of learning thru conditioning, somewhat along the lines of Skinner's experiments.

The influence of science and mathematics on learning theory is illustrated by the report by Wyckoff (76). His symbolic analysis of learning resulted in a mathematical model. He then constructed an electronic model to test whether his postulate system would yield plausible predictions. A related analysis of learning was made by Hovland (42). The application of learning theory to the learning of mathematics was treated extensively in the Twenty-First Yearbook of the National Council of Teachers of Mathematics (57). A summary of research on learning may be found in the December 1955 issue of the REVIEW OF EDUCATIONAL RESEARCH (26). The June 1956 issue (5) of this periodical was devoted to the topic, "Twenty-Five Years of Educational Research."

Concept Formation

Most of the activities in the science and mathematics classrooms are directed toward the mastery of important concepts. Carpenter (20) designed an experiment to test the hypothesis that a functional condition of concept formation which emphasizes meaningful learning results in greater retention of facts and understanding than concept learned by rote. He found that material which can be learned by the manipulation or study of objects is more thoroly understood than factual information given only by lecture. Bills (12) studied the effects of value on learning. A comparison of final marks afforded the conclusion that agreement or disagreement between students and instructors influenced marks even when based on objective examinations. The second conclusion was that a small class appeared to be more effective in overcoming this effect than did a large class. Mech and others (53) made an experimental analysis of differential reinforcement in classroom situations. The results of this study pointed up the desirability of teachers' using 100-percent verbal reinforcement in a massed fashion. Werner and Kaplan (75) completed a developmental study of the acquisition of word meaning. Haugh (40) found students could acquire a significant amount of information by reading or listening to radio drama. He found reading to be initially more effective than listening in acquiring information, but after a lapse of seven weeks there was no difference between the methods. No change in attitude resulted from a brief exposure to either reading or listening.

Burnett (17) used diagnostic tests and evaluation exercises to help the student build study skills. Even with supervised practice and remedial suggestions, little progress was made during the semester of study by the 24 students involved. A comparison of learning by eighth-grade social-studies classes using pupil-teacher planning and teacher-directed

procedures was made by Rehage (65). Differences in favor of the teacher-pupil planning group did not appear as frequently as was anticipated. Howell (43) tested the effectiveness of intensive instruction in the formation of work-study skills. A short experiment to test whether or not learning by understanding has an advantage over learning by rote was completed by Hilgard, Irvine, and Whipple (41). Learning by understanding was found to have very little advantage in a study of the tests used in this experiment.

The general trend of the studies on concept formation tends to verify accepted principles of learning altho the substantiation is not as strong as one would expect:

1. Learning that is meaningful is more effective than learning that lacks significance.
2. Learning takes place somewhat in proportion to the involvement of the learner in learning activities.
3. The role of the teacher as a guide or participant in pupil-teacher planning stimulates learning.
4. Manipulation and sensory learning continue to demonstrate superiority over verbal learning.
5. The goal acceptance by the learner appears to be involved in the learning situation.

In view of the wide acceptance and heavy emphasis on the inductive, discovery approach to learning, it is disappointing to find little research on these important aspects of learning. There is also a lack of studies dealing with levels of concept mastery and with the measurement of the level attained by a given student.

Motivation

The need for motivation before learning takes place has been accepted as an established fact. However, the word *motivation* has taken on new meaning. Motivation is now seen as coming from within the learner. The development of the concept of learning as a goal-directed activity has focused attention on the learner. But ways of producing effective motivation by traditional methods are still being subjected to experimental study.

Majumdar (52) experimented with the relative influence of reward and punishment on 200 school and college students from 11 to 25 years of age. He found the relative effect of punishment to be greater and quicker than reward with conditioning during learning being the most important factor. Motivation was related to experimentally induced failure by Russell (68) in a brief experiment with nonsense syllables. The effect of failure was reflected in a short disruption of performance and did not act as a motivator. However, the interaction between failure, motivation, and retention was not significant. A related study was completed by Fitch, Drucker, and Norton (33) on the motivational influence of frequent

testing. The results of this experiment with 295 college students indicated that frequent testing in a college lecture course did bring about a significant difference in achievement in favor of the tests.

The profit motive has been considered the basic incentive for progress in business. Bahrick (8) applied the principle to learning by using a monetary reward (from $1.50 to $10) for rapid learning; the more rapid the learning, the higher the pay. This incentive was sufficient to produce significantly higher results on one test of associating a geometric shape with a color. However, significantly lower results were attained by the incentive group on another test. Morgan (56) devised a "picture motivations" test to measure the achievement motivation of eleventh-grade students. He found low to moderate relationships existing between school achievement and degree of motivation. Differences in motivation between high- and low-scholarship college students were investigated by Brown, Abeles, and Iscoe (16). Attitude toward academic life and interest factors were found as important for scholarship as study habits, study aids, or native intelligence. Hurley (44) found that motivational instructions increased achievement of verbal learning and that achievement imagery (a measure of motivation) was positively related to performance under low motivation. Saltzman (69) suggested that previous experiments in incidental and intentional learning may be misleading because proper account was not taken of the "orienting task" required of incidental learners. A summary of current theory and research in motivation was presented by Brown and others (15).

This recent research in motivation reminds us that motivation is still a highly important aspect of learning. Success and praise continue to hold top rank as effective motivators. However, individuals vary greatly in their response to motivation, in the need for motivation, and in degree of motivation. In certain experiments the effects upon an individual subject were not always in line with the effect upon the group of which he was a member. As reported by Carroll (21), it seems that whether knowledge of success improves learning depends largely upon the needs and expectations of the learner. Altho most of the research involved the learning of nonsense material by college psychology students, the applicability of these results to the science and mathematics classroom seems reasonable when it is related to the individual.

Emotion and Learning

The role of emotions has come to be recognized as of increasing importance in the learning situation. Attitudes, anxieties, and interests appear highly effective in controlling the response of a student to a learning activity.

Castaneda, Palermo, and McCandless (22) and Palermo, Castaneda, and McCandless (59) performed a series of experiments to investigate

the relationship of anxiety to performance in a complex learning situation. A statistically significant interaction was found between anxiety and task difficulty. This interaction was based on the tendency for the performance of the high-anxious children to be inferior, in comparison with the low-anxious children, on the difficult components of the task but with a tendency for their performance to be superior on the less difficult components. A second experiment was concerned with the relationship of motivational level to performance in a trial-and-error learning situation. The results were in agreement with similar studies; the more anxious subjects made significantly more errors in the learning task than the less anxious subjects.

Billingslea and Bloom (11) designed a college classroom experiment to test the effects of frustration and success on goal-directed behavior. The trend was for the frustration group to take fewer notes and utilize adjustment mechanisms immediately following interference. After a period of 48 hours, the frustration group returned to its original level or a higher level of note taking. Hamza (38) compared two groups of boys; one group was retarded in mathematics altho normal in other subjects; the other group was regarded as normal in schoolwork. The results demonstrated the importance of the general intellectual factor, plus the "visual imagery" and "number" factors in mathematical ability. Motivational and attitudinal factors were found related to the problem of retardation in mathematics.

Bloom (13) studied the relation between three selected personality characteristics, the learning process in the classroom, and the achievement of students as revealed by examinations. In the examinations, the most anxious did as well as the others on questions demanding specific information, but relatively poorly on problems involving analysis, application, or synthesis. The rigid people were able to handle highly structured, specific, and familiar material, but were unable to interrelate such material or apply it to new situations in examinations. No relation was found between negativism and achievement on examinations. Smith (71) conducted an experiment that was concerned with the effects of the following variables and of their interactions on paired-associate learning and visual-recognition thresholds: hostility, nature of stimuli, and experimentally induced failure. He reported no over-all difference in the performance of the hostile and nonhostile subjects. Failure resulted in an impairment of learning which persisted thruout the learning task. Failure did not result in any over-all difference between the performance of hostile and nonhostile subjects.

Buswell (19) investigated whether or not children who are accepted by their peers differ in certain types of achievement from those who are rejected. The subjects were kindergarteners and fifth-graders in eight schools. The study showed that in general pupils who succeeded in their schoolwork also succeeded in their social relationships with their peers. Kuhlen and Collister (51) used data from social acceptance (guess who) tests given to 193 sixth-graders and 215 ninth-graders to detect differences

between those who graduated and those who did not finish. Generally the drop-outs represented a group of children who were physically unattractive, poorly groomed, lacking in social know-how, shy, withdrawn, and unhappy; in short they were personally and socially maladjusted individuals.

Ramond (64) investigated the effect of differences in motivational level upon performance in a verbal learning situation as a function of the relative strengths of the correct and incorrect responses in the initial hierarchies. He cited evidence that nonanxious subjects responded significantly more often than anxious subjects on those presentations in which the weaker response was correct. He found a significant difference between the performance of the anxious and nonanxious subjects on those presentations in which the stronger response was correct.

Perkins (60) found that classroom climate influenced group learning. Group-centered learning was superior in the formation of concepts, attitudes toward children, use of evidence to substantiate statements, and insight into and soundness of reasoning. Michael, Herrold, and Cryan (54) surveyed attitudes of students toward behavior and practices of teachers by means of a questionnaire administered to eleventh- and twelfth-grade pupils. The teacher's method of teaching, the teacher's personality, and confidence in the teacher's knowledge of subjectmatter were more important in determining enjoyment of a course than marks obtained, shortness of assignment, or limited emphasis on discipline. Pupils preferred teachers who participated in extracurriculum affairs of the school and also preferred teachers who allowed voluntary answers rather than teachers who called on specific individuals. No systematic relationship was found between scholastic averages of pupils and attitudes toward teachers. Montague (55) showed that anxious subjects performed best on easy tasks and less well on difficult tasks. Bijou (10) found that a discouraged, retarded child was motivated to complete a task when the work was related to his level of mental ability and previous achievement rather than to class standards. The role of anxiety in learning was also studied by Nicholson (58).

These studies suggest that the science and mathematics teacher must meet the social and emotional needs of students if he expects maximum achievement. The anxious student makes many errors, has difficulty in learning complex material, produces little work, and is distracted in problem analysis. The classroom with a learning climate that takes into account the needs of the student encourages superior learning of concepts, better attitudes, better reasoning skill, more participation in discussion, and fewer drop-outs. The student who is successful in academic work tends to be successful socially. On the other hand there is some evidence that anxiety may stimulate easy learning. This suggests that complete adjustment or lack of anxiety may mean a low level of motivation for learning. The key to the problem appears to be the learning climate established by the teacher.

Transfer of Training

Altho many issues remain to be settled in regard to transfer of training, little research has been done in this area. Porter and Duncan (61) investigated the hypothesis that there is negative transfer between two learning experiences when the second involves similar material. The results based on 40 university students substantiated the hypothesis at a statistically significant level.

In another study Duncan (29) reported that transfer increased directly both with the degree of first-task learning and with intertask similarity. He concluded that this was due to response generalization as well as to learning "how to learn." Harcum (39) found no significant differences in amount of effect between forward and backward association. Kostick (50) compared sex differences in the transfer of reasoning processes and found that boys exceeded girls in the transfer of training in generalizations. Baker and Wylie (9) studied the transfer of verbal training to a motor task and found that transfer was obtained even when both stimuli and response of the training task differed from those of the final task.

Atwater (6) experimented with retroactive inhibition and found it to be highly transitory. Retroactive inhibition increased as the prior learning increased until a relatively high degree of prior learning was reached after which it showed no significant change. These meager data may indicate that if something has been learned incorrectly, reteaching the correct material with the same stimuli might lead to reinforcement of the incorrect learning. The amount of transfer and the way to obtain maximum transfer continues to be a problem that needs extensive research with classroom materials and conditions.

Retention

The permanence of learning has come to be recognized as a major goal in learning. The amount of research involving this topic reflects this emphasis. Shaklee and Jones (70) studied the effects of three degrees of distribution of short practice periods prior to the first solution of a deductive-type problem. Little difference in retention was found between massed practice and distributed practice. Doten (28) found rest periods to have a negative effect on a long established verbal habit. Retention over a long period of time was considered by Duncan and Underwood (30). After a 14-month interval, forgetting was so great that performance on the recall trial was poorer than on the first acquisition trial. However, relearning was rapid and varied significantly with the degree of original mastery but not with similarity. Retroactive inhibition appeared to be very meager with respect to meaningful material according to Hall (37). The role of "learning how to retain" was related to retention by Greenberg and Underwood (35) with no decisive conclusion being reached.

Klare, Mabry, and Gustafson (48) studied the relationship of the human interest of reading material to its comprehensibility and acceptability thru the use of personal words and sentences. They found no significant difference in immediate retention, but human interest material was easier to read and more "acceptable" for reading. In a related study Ausebel and others (7) considered the influence of intent to remember in the retention of school learnings. He found no influence of intent on retention when intent was introduced after the original learning. Postman, Adams, and Bohm (63) found intentional learning to be superior to incidental learning altho the results of this study suggest that the associativeness of the learning is at least as important as intent in retention. Another report by Postman (62) discussed how the amount and quality of memory change when the subject is familiarized with the stimulus and is provided with general rules for classifying and ordering the individual items. An experiment by Underwood (73) on the influence of similarity of material on learning and retention gave inconclusive evidence that similarity was a factor in learning or retention of adjective lists. Irion and Wham (45) experimented with a prerecall warm-up recall. Significant differences were found in favor of greater retention among the warm-up group. Aborn (1) reported that his subjects did not counteract inhibiting effects by rehearsal, overlearning, or increased motivation. A related study was reported by Chasin (23) who investigated the effect of punishment of wrong responses in a law-of-effect experiment.

Hall's study (36) which found a relationship between word frequency and recall may have implications regarding the readability of science and mathematics textbooks. These textbooks may have difficult readability scores due to the technical vocabulary but the repetition of these technical words may need to be considered before it is concluded that the reading level is too difficult for the pupils involved.

From these studies it would seem that current emphasis on meaningful learning is justified. The more meaningful and associated the learning is, the greater is the retention. The studies also indicate the major roles of interest in and acceptance of learning activities by the pupil. The results remind us of the deadly effect of forgetting and the important role of practice in building retention.

Practice

Practice and drill continue to serve the functions of increasing the retention, efficiency, and accuracy of skill learning in mathematics and science. The kind of practice, the spacing of practice, and the motivation of practice continue to be unsolved learning problems in the classroom.

An extensive series of experiments on massed practice (reinforcement) versus spaced practice were carried out by Kapos, Mech, and Fox (46, 47). These experiments involved approximately 300 elementary-school pupils in each experiment, used good experimental designs which included

randomization and employed analysis of variance and covariance to determine the significance of differences in achievement and drive level in an arithmetic task. The analysis of covariance between the subgroups of differing intelligence levels within each reinforcement group indicated the absence of any relationship between intelligence and the effect of a fixed quantity of reinforcement. Practice according to a periodic schedule appeared superior to a random schedule of practice. The drive level of the high-ability pupil fell significantly below subjects of lower ability under 100-percent reinforcement (highest practice level). A program of 75-percent reinforcement appeared superior to higher or lower levels of reinforcement. Riley (67) also studied the relationship between distribution of practice and the complexity of the learning situation. He concluded that the general superiority of distributed practice is in large part due to effects operating early in the learning process. As practice continued, these beneficial effects of distributed practice tended to disappear. It seems possible that in a more complex situation there is actually a reversal with massed conditions becoming more beneficial.

In a study of the learning of motor skills Gagne (34) concluded that performance decrement as a result of massed or distributed practice did not occur consistently. Adams (3) reported that pacing was not an important learning variable in learning a psychomotor response. A statistically significant difference between the effects of positive and negative stimuli was obtained by Bond (14), but Kosofsky (49) found no difference between positive and negative guidance. Underwood (74) argued that distribution of practice was a learning variable. However, Adams and Reynolds (4) proposed that distribution of practice was a performance rather than a learning variable in their study of the relationship of rest to learning.

The implications of these few studies largely verify accepted theory, namely:

1. Spaced practice is generally superior to massed practice.
2. Practice is important in skill learning at all levels of ability, but the amount of practice needed varies with ability.
3. The effectiveness of practice depends on the nature of the learning which has preceded the practice and the nature of the skill being learned.
4. Practice needs adequate motivation if the reinforcement is to be optimum.

Conclusions

The above analysis of research in the field of learning indicates some change in the frame of reference but a continued emphasis on traditional factors in learning. There is a growing appreciation that the dynamics of personality plays a major role in determining not only how people learn but also what they learn. The result is an emphasis on the learner rather than on the teacher, the recognition of the role emotional adjustment plays in learning, and the role that learning plays in influencing personality

development. It follows that more attention needs to be given to how children feel about themselves, about others, and about learning. This attention to the individual points up the need for more case-study research instead of group research. However, there was no research found on teaching children how to work together, how to plan, or how to evaluate what they have learned. These are goals modern education has accepted as being as important as facts, skills, and problem solving. Current research still is largely focused on the outcome rather than on the process, on specifics rather than configurations, and on isolated learning rather than on relationships and generalizations. With current emphasis on the interrelationships of all the factors in learning, research becomes more complex and illusive. When learning is recognized as having many facets and causes, the classification of learning as intellectual, motor, and emotional is meaningless. And the interpretation of research that deals with minor details of the learning situation is also meaningless. Future research will need to focus on the deeper motivations that determine children's learning. Little has been done with specific learning problems or in specific school subjects to take into account the intensely personal nature of learning and the selectivity of perception. Relatively little of the research done during recent years has been a part of an over-all design for attacking fundamental learning problems. If the necessary funds were available, it would seem possible to set up large-scale projects involving teachers and pupils from various areas. With carefully developed experimental designs, work with some of the pressing problems over a long period of time would yield results in which one could have confidence.

The psychologist, the statistician, and the educator continue to work in an uncoordinated fashion. The psychologist is concerned with learning experimentation that is far removed from everyday classroom problems. The statistician has tools and experimental designs that are difficult to use in the classroom situation. And the educator plans curriculums, learning activities, and classroom materials that satisfy current philosophies of learning. The methods of mathematics and science need to be used to coordinate the resources of each of these specialists in solving the problems of science and mathematics education.

Bibliography

1. ABORN, MURRAY. "The Influence of Experimentally Induced Failure on the Retention of Material Acquired Through Set and Incidental Learning." *Journal of Experimental Psychology* 45: 225-31; April 1953.
2. ADAMS, DONALD K. "Learning and Explanation." *Learning Theory, Personality Theory, and Clinical Research: The Kentucky Symposium.* New York: John Wiley and Sons, 1954. p. 66-80.
3. ADAMS, JACK A. "Effect of Pacing on the Learning of a Psychomotor Response." *Journal of Experimental Psychology* 47: 101-105; February 1954.

4. ADAMS, JACK A., and REYNOLDS, BRADLEY. "Effect of Shift in Distribution of Practice Conditions Following Interpolated Rest." *Journal of Experimental Psychology* 47: 32-36; January 1954.
5. AMERICAN EDUCATIONAL RESEARCH ASSOCIATION. "Twenty-Five Years of Educational Research." *Review of Educational Research* 26: 199-344; June 1956.
6. ATWATER, STEPHEN K. "Proactive Inhibition and Associative Facilitation as Affected by Degree of Prior Learning." *Journal of Experimental Psychology* 46: 400-404; December 1953.
7. AUSEBEL, DAVID, and OTHERS. "The Influence of Intention on Retention of School Materials." *Journal of Experimental Psychology* 53: 87-93; February 1957.
8. BAHRICK, HARRY P. "Incidental Learning under Two Incentive Conditions." *Journal of Experimental Psychology* 47: 170-72; March 1954.
9. BAKER, KATHERINE E., and WYLIE, RUTH C. "Transfer of Verbal Training to a Motor Task." *Journal of Experimental Psychology* 40: 632-38; October 1950.
10. BIJOU, SIDNEY W. "Motivation in the Academic Learning of the Retarded Child." *Exceptional Children* 19: 103-104; December 1952.
11. BILLINGSLEA, FRED Y., and BLOOM, HERBERT. "The Comparative Effect of Frustration and Success on Goal-Directed Behavior in the Classroom." *Journal of Abnormal and Social Psychology* 45: 510-15; July 1950.
12. BILLS, ROBERT E. "The Effect of a Value on Learning." *Journal of Personality* 21: 217-22; December 1952.
13. BLOOM, BENJAMIN S. "Personality Variables and Classroom Performance." *Journal of the National Association of Deans of Women* 16: 159-64; June 1953.
14. BOND, JAMES G. *A Study of the Comparative Effects of Positive and Negative Stimuli in a Non-Verbal Learning Situation.* Doctor's thesis. New York: New York University, 1954. 114 p. Abstract: *Dissertation Abstracts* 15: 226-27; No. 2, 1955.
15. BROWN, JUDSON S., and OTHERS. *Current Theory and Research in Motivation: A Symposium.* Lincoln: University of Nebraska Press, 1953. 193 p.
16. BROWN, WILLIAM F.; ABELES, NORMAN; and ISCOE, IRA. "Motivational Differences Between High and Low Scholarship College Students." *Journal of Educational Psychology* 45: 215-23; April 1954.
17. BURNETT, COLLINS W. "Study Skills and Counselor Trainings: A Two-Way Teaching Program." *California Journal of Educational Research* 2: 18-21; January 1951.
18. BUSWELL, GUY T., and KERSH, BERT Y. *Patterns of Thinking in Solving Problems.* University of California Publications in Education, Vol. 12, No. 2. Berkeley: University of California Press, 1956. p. 63-148.
19. BUSWELL, MARGARET M. "The Relationship Between the Social Structure of the Classroom and the Academic Success of the Pupils." *Journal of Experimental Education* 22: 37-52; September 1953.
20. CARPENTER, FINLEY. "The Effect of Different Learning Methods on Concept Formation." *Science Education* 40: 282-85; October 1956.
21. CARROLL, HERBERT A. "Motivation and Learning: Their Significance in a Mental-Health Program for Education." *Mental Health in Modern Education.* Fifty-Fourth Yearbook, Part II, National Society for the Study of Education. Chicago: University of Chicago Press, 1955. Chapter 3, p. 59-81.
22. CASTANEDA, ALFRED; PALERMO, DAVID S.; and MCCANDLESS, BOYD R. "Complex Learning and Performance as a Function of Anxiety in Children and Task Difficulty." *Child Development* 27: 327-32; September 1956.
23. CHASIN, JOSEPH B. *A Study of Cumulative Punishment in a Law of Effect Experiment.* Doctor's thesis. New York: Columbia University, 1953. 79 p. Abstract: *Dissertation Abstracts* 14: 63-64; No. 1, 1954.
24. DAILY, JOHN M. *Verbal Conditioning Without Awareness.* Doctor's thesis. Iowa City: State University of Iowa, 1953. 76 p. Abstract: *Dissertation Abstracts* 13: 1247-48; No. 6, 1953.
25. DAWSON, HERBERT E., JR. *Concurrent Conditioning of Autonomic Processes in Humans.* Doctor's thesis. Bloomington: University of Indiana, 1953. 118 p. Abstract: *Dissertation Abstracts* 14: 189; No. 1, 1954.
26. DELONG, ARTHUR R. "Learning." *Review of Educational Research* 25: 438-52; December 1955.

27. DENNY, M. RAY, and ADELMAN, HARVEY M. "Elicitation Theory: I. An Analysis of Two Typical Learning Situations." *Psychological Review* 62: 290-96; July 1955.
28. DOTEN, GEORGE W. "The Effect of Rest Periods on the Interference of a Well-established Habit." *Journal of Experimental Psychology* 49: 401-406; June 1955.
29. DUNCAN, CARL P. "Transfer in Motor Learning as a Function of Degree of First-Task Learning and Inter-Task Similarity." *Journal of Experimental Psychology* 45: 1-11; January 1953.
30. DUNCAN, CARL P., and UNDERWOOD, BENTON J. "Retention of Transfer in Motor Learning after 24 Hours and after 14 Months." *Journal of Experimental Psychology* 46: 445-53; December 1953.
31. ENGLISH, HORACE B. *The Historical Roots of Learning Theory.* New York: Doubleday and Co., 1954. 21 p.
32. ESTES, WILLIAM K., and OTHERS. *Modern Learning Theory: A Critical Analysis of Five Examples.* New York: Appleton-Century-Crofts, 1954. 379 p.
33. FITCH, MILDRED L.; DRUCKER, A. J.; and NORTON, J. A., JR. "Frequent Testing as a Motivating Factor in Large Lecture Classes." *Journal of Educational Psychology* 42: 1-20; January 1951.
34. GAGNE, ROBERT M. "Work Decrement in the Learning and Retention of Motor Skills." *Symposium on Fatigue.* (Edited by W. F. Floyd and A. T. Welford.) London: H. K. Lewis, 1953. p. 155-62.
35. GREENBERG, RUTH, and UNDERWOOD, BENTON J. "Retention as a Function of Stage of Practice." *Journal of Experimental Psychology* 40: 452-57; August 1950.
36. HALL, JOHN F. "Learning as a Function of Word Frequency." *American Journal of Psychology* 67: 138-40; March 1954.
37. HALL, JOHN F. "Retroactive Inhibition in Meaningful Material." *Journal of Educational Psychology* 46: 47-52; January 1955.
38. HAMZA, MUKHTAR. "Retardation in Mathematics Amongst Grammar School Pupils." *British Journal of Educational Psychology* 22: 189-95; November 1952.
39. HARCUM, E. RAE. "Verbal Transfer of Overlearned Forward and Backward Associations." *American Journal of Psychology* 66: 622-25; October 1953.
40. HAUGH, OSCAR M. "The Relative Effectiveness of Reading and Listening to Radio Drama as Ways of Imparting Information and Shifting Attitudes." *Journal of Educational Research* 45: 489-98; March 1952.
41. HILGARD, ERNEST R.; IRVINE, ROBERT P.; and WHIPPLE, JAMES E. "Rote Memorization, Understanding, and Transfer: An Extension of Katona's Card-Trick Experiments." *Journal of Experimental Psychology* 46: 288-92; October 1953.
42. HOVLAND, CARL I. "A 'Communication Analysis' of Concept Learning." *Psychological Review* 59: 461-72; November 1952.
43. HOWELL, WALLACE J. "Concept Formation of Work-Study Skills by Use of Autobiographies in Grade Four." *Journal of Educational Psychology* 44: 257-65; May 1953.
44. HURLEY, JOHN R. "Achievement Imagery and Motivational Instructions as Determinants of Verbal Learning." *Journal of Personality* 25: 274-82; March 1957.
45. IRION, ARTHUR L., and WHAM, DOROTHY S. "Recovery from Retention Loss as a Function of Amount of Pre-Recall Warming-Up." *Journal of Experimental Psychology* 41: 242-46; April 1951.
46. KAPOS, ERVIN; MECH, EDMUND V.; and FOX, WILLIAM H. *Schoolroom Motivation: I. Two Studies of Quantity and Pattern of Verbal Reinforcement as Related to Performance on a Routine Task.* Bulletin of the School of Education, Vol. 33, No. 1. Bloomington: Indiana University, January 1957. 43 p.
47. KAPOS, ERVIN; MECH, EDMUND V.; and FOX, WILLIAM H. *Schoolroom Motivation: II. Two Studies of Quantity and Pattern of Verbal Reinforcement as Related to a Measure of Drive on a Routine Task.* Bulletin of the School of Education, Vol. 33, No. 2. Bloomington: Indiana University, March 1957. 40 p.
48. KLARE, GEORGE R.; MABRY, JAMES E.; and GUSTAFSON, LEVARL M. "The Relationship of Style Difficulty to Immediate Retention and to Acceptability of Technical Material." *Journal of Educational Psychology* 46: 287-95; May 1955.

49. KOSOFSKY, SIDNEY. "The Effectiveness of Positive and Negative Guidance as Related to the Degree of the Organization of the Material To Be Learned." *Journal of General Psychology* 47: 91-104; July 1952.
50. KOSTICK, MAX M. "A Study of Transfer: Sex Differences in the Reasoning Process." *Journal of Educational Psychology* 45: 449-58; December 1954.
51. KUHLEN, RAYMOND G., and COLLISTER, E. GORDON. "Sociometric Status of Sixth- and Ninth-Graders Who Fail To Finish High School." *Educational and Psychological Measurement* 12: 632-37; Winter 1952.
52. MAJUMDAR, K. "An Experimental Study of the Relative Influence of Reward and Punishment on Learning." *Indian Journal of Psychology* 26: 67-72; 1951.
53. MECH, EDMUND V., and OTHERS. *An Experimental Analysis of Patterns of Differential Verbal Reinforcement in Classroom Situations.* Bulletin of the School of Education, Vol. 29, No. 5. Bloomington: Indiana University, September 1953. 24 p.
54. MICHAEL, WILLIAM B.; HERROLD, EARLE E.; and CRYAN, EUGENE W. "Survey of Student-Teacher Relationships." *Journal of Educational Research* 44: 657-73; May 1951.
55. MONTAGUE, ERNEST K. "The Role of Anxiety in Serial Rote Learning." *Journal of Experimental Psychology* 45: 91-96; February 1953.
56. MORGAN, HENRY H. "Measuring Achievement Motivation with Picture Interpretations." *Journal of Consulting Psychology* 17: 289-92; August 1953.
57. NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS. *The Learning of Mathematics, Its Theory and Practice.* Twenty-First Yearbook. Washington, D. C.: the Council, a department of the National Education Association, 1953. 355 p.
58. NICHOLSON, WILLIAM M. *A Test of Interference vs. Drive Increment Theory of the Influence of Anxiety upon Learning.* Doctor's thesis. Philadelphia: University of Pennsylvania, 1955. 47 p. Abstract: *Dissertation Abstracts* 15: 887-88; No. 5, 1955.
59. PALERMO, DAVID S.; CASTANEDA, ALFRED; and MCCANDLESS, BOYD R. "The Relationship of Anxiety in Children to Performance in a Complex Learning Task." *Child Development* 27: 333-37; September 1956.
60. PERKINS, HUGH V., JR. "Climate Influences Group Learning." *Journal of Educational Research* 45: 115-19; October 1951.
61. PORTER, LYMAN W., and DUNCAN, C. P. "Negative Transfer in Verbal Learning." *Journal of Experimental Psychology* 46: 61-64; July 1953.
62. POSTMAN, LEO J. *Learned Principles of Organization in Memory.* Psychological Monographs, No. 374. Washington, D. C.: American Psychological Association, 1954. 24 p.
63. POSTMAN, LEO; ADAMS, PAULINE; AND BOHM, AUDREY M. "Studies in Incidental Learning: V. Recall for Order and Associative Clustering." *Journal of Experimental Psychology* 51: 334-42; May 1956.
64. RAMOND, CHARLES K. "Anxiety and Task as Determiners of Verbal Performance." *Journal of Experimental Psychology* 46: 120-24; August 1953.
65. REHAGE, KENNETH J. "A Comparison of Pupil-Teacher Planning and Teacher-Directed Procedures in Eighth Grade Social Studies Classes." *Journal of Educational Research* 45: 111-15; October 1951.
66. RESTLE, FRANK. "A Theory of Discrimination Learning." *Psychological Review* 62: 11-19; January 1955.
67. RILEY, DONALD A. "Rote Learning as a Function of Distribution of Practice and Complexity of the Situation." *Journal of Experimental Psychology* 43: 88-95; February 1952.
68. RUSSELL, WALLACE A. "Retention of Verbal Material as a Function of Motivating Instructions and Experimentally-Induced Failure." *Journal of Experimental Psychology* 43: 207-16; March 1952.
69. SALTZMAN, IRVING J. "The Orienting Task in Incidental and Intentional Learning." *American Journal of Psychology* 66: 593-97; October 1953.
70. SHAKLEE, ALFRED B., and JONES, B. EDSON. "Distribution of Practice Prior to Solution of a Verbal Reasoning Problem." *Journal of Experimental Psychology* 46: 429-34; December 1953.
71. SMITH, JOSEPH G. "Influence of Failure, Expressed Hostility, and Stimulus Characteristics on Verbal Learning and Recognition." *Journal of Personality* 22: 475-93; June 1954.

72. SWENSON, ESTHER J.; ANDERSON, G. LESTER; and STALEY, CHALMERS L. *Learning Theory in School Situations.* University of Minnesota, Studies in Education, No. 2. Minneapolis: University of Minnesota Press, 1949. 103 p.
73. UNDERWOOD, BENTON J. "Studies of Distributed Practice: X. The Influence of Intralist Similarity on Learning and Retention of Serial Adjective Lists." *Journal of Experimental Psychology* 45: 253-59; April 1953.
74. UNDERWOOD, BENTON J. "Studies of Distributed Practice: XII. Retention Following Varying Degrees of Original Learning." *Journal of Experimental Psychology* 47: 294-300; May 1954.
75. WERNER, HEINZ, and KAPLAN, EDITH. *The Acquisition of Work Meanings: A Developmental Study.* Society for Research in Child Development Monographs, No. 51. Lafayette, Ind.: Child Development Publications, 1950. 120 p.
76. WYCKOFF, L. BENJAMIN. "A Mathematical Model and an Electronic Model for Learning." *Psychological Review* 61: 89-97; March 1954.

CHAPTER IX

Programs in Mathematics and Science Teaching

I. E. WALLEN

ALTHO the REVIEW has not usually included descriptions of research before publication, the committee planning this issue believed that it would be desirable to attempt to describe some of the many current programs in science and mathematics education.

One of the more unique studies is being operated by the Committee on Educational Policies of the Biology Council of the National Research Council. A list of questionnaire items has been formulated, dealing with such things as the recruitment, continuing education, assignment, working conditions, social and economic status, and future plans of teachers; school enrolments and requirements in science and mathematics; content of biology courses; use of the laboratory; field trips; projects; club work; textbooks, manuals, and libraries; and facilities and equipment. An 80-item questionnaire is now available for those who may need to consult it for ideas.

The National Committee for the Development of Scientists and Engineers has given encouragement to this type of questionnaire in which a number of national agencies are interested. The U.S. Office of Education plans to make a comprehensive study of a 10-percent sample of science and mathematics teachers thruout the United States to determine their status. The data obtained will be used by many organizations, including the Scientific Manpower Commission, the Engineers Joint Council, the National Education Association, and the American Association for the Advancement of Science, in their programs concerned with future needs in research and teaching. Studies of enrolments are made annually by the American Chemical Society as well as by the U.S. Office of Education and departments of the National Education Association.

Using the statistics secured by these manpower groups, several different kinds of programs have been designed to provide direct or indirect assistance to teachers and students and to increase the academic competence of the teacher either before original certification or by providing further education after certification thru the return of the teacher to the campus.

AAAS Study on Science Counselors

A study of the use of science counselors was developed by the Cooperative Committee of the American Association for the Advancement of Science and implemented thru the Science Teaching Improvement Program of AAAS. Four university centers were designated. Each center consists of a state university and a territory surrounding it so bounded as to contain as many secondary schools cooperating in the project as would be required to include approximately 100 full-time science and mathematics

teachers. Each university has employed two counselors and appointed a coordinator who is responsible primarily to a committee of persons from the science departments of that university. Staff members of each university are available to assist the counselors. The counselors also seek advice and assistance from the state departments of education.

The study is planned to test the effectiveness of a program in terms of six objectives: (a) improving the science and mathematics instruction in secondary schools thru the use of teacher-counselors; (b) providing in-service aid to teachers of science and mathematics with stress on most recent developments, improved laboratory and demonstration technics, and good teaching methods; (c) bringing university staff members and science and mathematics educators into closer relationships on problems of common concern; (d) bringing university science and mathematics staffs into closer touch with secondary schools; (e) providing direct services to universities and secondary schools; and (f) providing a means of increasing the cooperation between staff members of universities and state departments of education.

Traveling Libraries and Visual Aids

Another program of considerable interest to the secondary-school teacher is the use of various types of library services. The AAAS is carrying on an experimental program in the effective use of science books by secondary-school students. The general purposes of the Traveling High School Science Library Program are to stimulate an interest in reading science and mathematics books, to broaden the science background of high-school students, and to assist students who have an interest in science and mathematics in choosing professional careers. Most books have been chosen because of their appeal to the general reader who has little or no background in science.

The traveling library consists of 200 books divided into eight units of 25 books each. One unit is placed in a small traveling case that can also be used for displaying the books in the school library. During the experimental period the participating schools receive 50 books which can be used for a period of two months. At the end of each two-month period, units are exchanged so that by the end of the school year all schools have received and used all 200 books. The AAAS is conducting a study to evaluate the effectiveness of the Traveling High School Science Library Program and to assess the interest of high-school students in the individual books in the library. The basis of this study will be records of books borrowed, circularization at program schools, and questionnaires to be completed by students at the program schools and at selected matching control schools that are not receiving the library.

Library materials are also available from the American Chemical Society, the Atomic Energy Commission, and the Manufacturing Chemists Association for participating schools.

Closely related to the distribution of books are the programs of the Atomic Energy Commission for the provision of equipment and teaching aids. The Commission makes financial grants to assist educational institutions in acquiring specialized equipment for education and training in radiation biology and for staff use in handling radioisotopes in research. The purpose of these grants is to encourage the training of medical students, graduate students, and physicians in the use of radioisotopes in medicine, biology, and agriculture. Radioisotope kits, which include radioisotopes, neutron sources, and detecting and counting instruments, are presented to those high-school teachers attending cooperative radioisotope summer institutes of the Commission and the National Science Foundation. The Commission also makes grants to help nonprofit collegiate institutions acquire teaching aids, demonstration apparatus, and library equipment to be used primarily for education purposes in nuclear energy, agriculture, biology, and medicine.

In a related type of activity, the Manufacturing Chemists Association encourages its member companies to provide obsolete, used, or other available materials to teachers for use in the classroom. For direct assistance in certain instructional areas, both the Atomic Energy Commission and the Manufacturing Chemists Association provide exhibits that may be used by the secondary-school teacher.

Curriculum

One of the most difficult jobs of the secondary-school teacher is to maintain a continuing flow of modern scientific information to his classroom so that he may take advantage of these developments to maintain the interest of his students in science and mathematics. The National Council of Teachers of Mathematics regularly produces yearbooks, filmstrips, pamphlets, guidance materials, and booklets covering most phases of classroom instruction, from designing the mathematics classroom to modern developments in mathematics. The Commission on Mathematics of the College Entrance Examination Board is attempting to resolve such questions as: What content material should be omitted from the present secondary-school curriculums? What content material should replace it? What should be the objectives of secondary-school mathematics? What particular preservice and inservice programs of teacher education are desirable?

The Commission is preparing presentations of such topics as the fundamental concepts of probability and statistical inference, the concept of function, the idea of sets, and related topics in the secondary schools. The Mathematical Association of America also has active educational committees which are concerned with curriculum at the college level.

The Committee on Education Policies of the Division of Biology and Agriculture of the National Academy of Sciences, National Research Council, is examining all the courses in biology in order to make specific

suggestions concerning the organization and content of biology in its various disciplines for college and secondary-school study. As a result of a nationwide solicitation for ideas, source books of laboratory and field studies for secondary-school biology courses and for college courses in the biological sciences will be published. Twenty high-school teachers selected in a nationwide competition and 10 college and university biologists have been appointed to develop these exercises for publication from the more than 1300 exercises contributed by several hundred biologists.

Source books in physiology are being developed in cooperation with a Committee of the American Physiological Society, and source books in other disciplines are also likely to involve collaboration with appropriate professional organizations.

Experiments with direct curriculum materials for use in both elementary and secondary schools are under way thru the Manufacturing Chemists Association, the National Aviation Education Council, and indirectly thru some of the programs of the National Science Foundation.

Two of the fields of science are using tests in the recruitment and training of scientists. The American Chemical Society has developed tests primarily for the placement of college freshmen in proper courses. The Mathematical Association of America has also used placement tests.

Interesting Students in Science

As the scientific career horizons have widened, education interests, professional and business groups, industrial organizations, governmental agencies and others have increased their efforts to let potential scientists know what the job prospects are. Full-page advertisements have appeared in most nationally distributed magazines and newspapers. Films on careers in most fields have been produced by interested agencies. Filmstrips, posters, and other eye-catching devices have become common aids for guidance personnel.

Many industrial companies and business concerns publish guidance pamphlets and booklets. The American Chemical Society distributes approximately 75,000 copies of its guidance booklet annually; the National Association of Manufacturers, over 70,000 copies of its booklet. An important function of the National Science Teachers Association, thru its Future Scientists of America Foundation, has been to distribute packets of career information to high-school teachers. A booklet, *Keys to Careers*, was developed to describe the major sources of material to encourage future scientists. A compendium of careers in health has been developed by the Biology Council of the National Academy of Sciences, National Research Council. Many mailings, including career materials, are made by Science Service. The mathematical associations distribute a guidance pamphlet for careers in that field.

Since it has become obvious that a large number of young people are needed in science and mathematics fields, a special program of science

fairs has been developed primarily to assist young people in choosing their careers. The Oak Ridge Institute of Nuclear Studies, thru its museums division, provides considerable sums of money for conferences, descriptive pamphlets, project suggestions, and information for the teacher who is interested in participating in science fairs. A national science fair organization has been developed thru the activity of Science Service, where publications and professional advice can be secured on the operation of science fairs.

For further assistance to secondary schools, a speakers bureau is maintained by a number of agencies. One of the most effective of these operates thru the American Chemical Society, where 1800 speakers gave 3000 talks to approximately 175,000 persons during 1956. A very active speakers bureau is maintained by the Atomic Energy Commission at most of its installations, with scientists available for many kinds of talks to various groups. The National Science Foundation, the Oak Ridge Institute of Nuclear Studies, and, in industry, the Hughes Aircraft Company have developed significant programs of this type. In addition to these national or regional programs, a speakers bureau of special importance has been organized thru the Joint Board of Science Education of the Greater Washington Area. This organization provides speakers on a wide variety of subjects for use in the local schools in connection with educational activities.

Institutes and Fellowships

Perhaps the most important single development specifically for mathematics and science teachers is the summer institute program. The summer institute programs have been supported by the American Chemical Society for several years, with financial aid from the National Science Foundation. The Shell Companies Foundation has sponsored summer institutes for some time, as have DuPont and certain other large industries. Several universities, such as Case Institute of Technology, Cornell University, Harvard, and the Oak Ridge Institute of Nuclear Studies, have held annual institutes with constant support from outside organizations. The National Science Foundation has become the largest supporter of institutes with 96 institutes being convened during 1957, with their expenses underwritten by NSF.

The Atomic Energy Commission has recently become interested particularly in institutes for biology teachers. Support is being given to radiation biology institutes with the teachers receiving radioactive materials for classroom use after the institute.

The institutes provide funds so that a teacher can afford to go to school and improve his academic training during the summer. They usually provide funds to take care of the expenses and instruction incurred by the college or university as a result of the influx of teachers. Compensation in

the institute tends to be in accordance with what the teacher might have been able to earn had he engaged in a summer job.

The National Science Foundation and others have supported many conferences of shorter duration, especially thru the American Chemical Society, the Mathematical Association of America, the American Association for the Advancement of Science, and other national groups.

Another important assistance to teachers is concerned with scholarships and fellowships. Many opportunities for graduate and undergraduate study are provided thru the Atomic Energy Commission and the National Science Foundation. Programs of the National Academy of Science include provisions for long- or short-term scholarships. The American Chemical Society has administered a number of scholarships as have many other organizations of similar nature.

Some types of fellowships that have received most attention are those of the Atomic Energy Commission. From 1950 to 1957 the Oak Ridge School of Reactor Technology at the Oak Ridge National Laboratory graduated 589 students. The International School for Nuclear Science and Engineering graduated 162 persons of which 116 were from 34 foreign countries and 46 from the United States.

The Oak Ridge Institute of Nuclear Studies provides experimental medical and radiological residencies and training in the effective use of radioisotopes in research. Courses are offered approximately six times each year, with many special topics. More than 2800 students have received training in this program. Fellowships in radiological physics have had 279 participants since 1951. Fellowships in industrial hygiene have had 31 participants since 1953. Fellowships in industrial medicine have been accepted by 32 physicians.

The National Science Foundation awarded 1059 fellowships in four programs announced in March 1957 alone. These fellowships include predoctoral fellowships with first-year, intermediate, and terminal year programs; post-doctoral fellowships; senior post-doctoral fellowships, and science faculty fellowships. Thru support of research activities during 1952-1956, the Foundation supported advance training for more than 2900 graduate students.

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REVIEW OF EDUCATIONAL RESEARCH

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Single copies prior to 1949, $1; 1949 thru June 1957, $1.50; October 1957 to date, $2 each. Discounts on quantity orders. Orders should be sent to 1201 Sixteenth Street, N. W., Washington 6, D. C.

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Forthcoming Issues

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PHILOSOPHICAL AND SOCIAL FRAMEWORK OF EDUCATION. February 1958. Herman G. Richey, *Chairman.*

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* Out of print.